Chapter 7. Marine Cargo Imports and Forest Pest Introductions

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Why Is Marine Cargo Important to Forest Health?

A major pathway for the introduction of nonindigenous forest pests is accidental transport on cargo imported from overseas. Diseases may be brought into the United States via commercial trade of nursery stock or other live plant material, as has been suggested for *Phytophthora ramorum*, the pathogen that causes sudden oak death (Ivors and others 2006). Insects may similarly hitchhike on live plants, but may be more commonly transported on or in raw logs, wood products, dunnage (materials used to space or brace cargo loads), and solid wood packing materials. Pallets, crates, and other materials used to protect and contain goods for shipment are often made from poor-quality wood that is in many cases not fully debarked (Campbell 2001). Such materials are particularly good vectors for bark beetles and wood boring insects, which can survive in the materials throughout the shipment duration (Brockerhoff and others 2006, Haack 2006).

With expanding global trade, the impacts of introduced pests on U.S. forests are likely to rise substantially (Levine and D'Antonio 2003). Not all introduced species become established, but varieties that are well adapted to become established in U.S. forests are more likely to arrive if introductions of individual species increase (Campbell 2001). Currently, national-scale risk assessments quantify the level of threat that individual pests represent to the United States based on biological and other information gathered from other countries. Analyses of pest interception databases such as the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS), Port Information Network (PIN) identify the pests most commonly detected during inspections at marine ports (e.g., Haack 2001, 2006; McCullough and others 2006), although only a small fraction (approximately 2 percent) of incoming cargo is subject to such inspection (National Research Council 2002). These analyses do not provide spatial information about which parts of the United States face the greatest risk from forest pest introductions. However, by analyzing statistical data on foreign cargo imports, it is possible to examine trends in the amount of high-risk cargo arriving at ports of entry as well as the geographic relationship of those ports to forested landscapes of the United

States. Such work yields a basic picture of where the risks from introduced forest pests are the greatest and may suggest locations in which to prioritize monitoring or management measures.

Methods

Data on foreign marine cargo imports were acquired from the U.S. Army Corps of Engineers Navigation Data Center (2006). The available data, spanning the years 1997 to 2004, were compiled into a table of more than 40,000 unique records. Each record lists the foreign port of origin, the U.S. marine port destination, and the weight tonnage (short tons) of a given commodity category unloaded at that port. Commodity categories are described by a two-digit code from the Navigation Data Center's Lock Performance Monitoring System (table 7.1).

The data coding system does not include a distinct category for live plants—the most likely pathway for forest pathogen introductions—so analysis was restricted to commodities on which forest insects are likely to be introduced. High-risk commodity categories were identified

Table 7.1—Commodity categories for U.S. marine cargo statistics data

Commodity code	Commodity description	Included in analysis
0	Units (ferried autos, passengers, railway cars)	
10	Coal, lignite, and coal coke	
20	Petroleum and petroleum products	
21	Crude petroleum	
22	Gasoline, jet fuel, kerosene	
23	Distillate, residual, and other fuel oils; lube oil and greases	
24	Petroleum pitches, coke, asphalt, naptha, and solvents	
29	Petroleum products not elsewhere classified	
30	Chemicals and related products	
31	Fertilizers	
32	Other chemicals and related products	
40	Crude materials, inedible except fuels	
41	Forest products, lumber, logs, woodchips	Yes
42	Pulp and waste paper	
43	Sand, gravel, stone, rock, limestone, soil, dredged material	Yes
44	Iron ore, iron and steel waste and scrap	
45	Marine shells	
46	Nonferrous ores and scrap	
47	Sulphur (dry), clay, and salt	
48	Slag	
49	Other nonmetallic minerals	
50	Primary manufactured goods	Yes
51	Paper and allied products	Yes
52	Building cement and concrete; lime; glass	Yes
53	Primary iron and steel products (ingots, bars, rods, etc.)	Yes
54	Primary nonferrous metal products; fabricated metal products	Yes

continued

Table 7.1—Commodity categories for U.S. marine cargo statistics data (continued)

Commodity code	Commodity description	Included in analysis
55	Primary wood products; veneer; plywood	Yes
60	Food and farm products	
61	Fish	
62	Wheat	
63	Corn	
64	Barley, rye, oats, rice, and sorghum grains	
65	Oilseeds (soybean, flaxseed, and others)	
66	Vegetable products	
67	Animal feed, grain mill products, flour, processed grains	
68	Other agricultural products; food and kindred products	
70	All manufactured equipment, machinery and products	Yes
80	Waste material; garbage, landfill, sewage sludge, waste water	
89	Waste and scrap not elsewhere classified	
90 or 99	Unknown or not elsewhere classified	

based on the types of cargo associated with forest insects in the APHIS PIN database: forest products or commodities that are typically shipped with wood packaging (table 7.1). Two-digit commodity codes offer limited thematic resolution, so some of the identified categories include goods that are regularly wood packaged and others that typically do not involve wood packing materials. These categories were used in the analysis under the assumption that a substantial proportion of their total tonnage involved some wood packaging, and that proportions did not vary much between ports, and so would not affect the ports' relative rankings in terms of total imports.

The total tonnage of all selected commodities arriving between 1997 and 2004 was calculated for each of the ports, which were then mapped based on coordinates from the U.S. National Transportation Atlas Databases (U.S. Department of Transportation, Bureau of Transportation Statistics 2005). To illustrate possible geographic relationships between ports and introduced pests, county-level distributions of several forest insects that have emerged in the United States during the last 10 years (table 7.2) were mapped in combination with the ports. The selected insect pests have already caused mortality in U.S. forest species or represent a high risk of establishment and spread.

Some marine cargo is shipped in large metal containers that are not opened prior to reaching their final inland destination. Nevertheless, a substantial majority (95 percent CI = 64 ± 1 percent) of freight tonnage is shipped 160 km (100 miles) or less within the United States, regardless of transport mode (U.S. Department of Transportation, Bureau of Transportation Statistics; U.S. Department of Commerce, U.S. Census Bureau 2005). Furthermore, marine port terminals and their nearby distribution facilities receive a large quantity of crating, dunnage, and other materials that may harbor forest pests. These packing materials may sit in open air for some time (Campbell 2001), and a flying insect might move from these materials to forested

Table 7.2—Notable forest insect pests detected in the United States since 1996

Species	First detected	Description
Asian longhorned beetle *(Anoplophora glabripennis)*	1996	Causes mortality in a variety of hardwood species. Infestations have already caused damage in a few U.S. urban areas, leading to extensive quarantine and eradication efforts (U.S. Department of Agriculture, APHIS 2006).
Redbay ambrosia beetle *(Xyleborus glabratus)*	2002	Pest of Lauraceae family. In the United States, has been associated with mortality of redbay (*Persea borbonia*) and has been detected on sassafras (*Sassafras albidum*). Uncertain if it will have a major economic impact (Haack 2006, Rabaglia 2003).
Emerald ash borer *(Agrilus plannipennis)*	2002	Causes significant mortality of ash (*Fraxinus*) species. Has spread beyond quarantine zones in both the United States and Canada (McCullough and Katovich 2004).
Sirex wood wasp *(Sirex noctilio)*	2004	Major pest of *Pinus* plantations in New Zealand, Australia, South Africa, and South America. Usually attacks stressed trees first (Hoebeke and others 2005).
Mediterranean pine engraver *Orthotomicus erosus)*	2004	Pest of many *Pinus* species in the Mediterranean, Middle East, Central Asia, and China with numerous suitable hosts throughout the United States. Usually does not attack healthy trees (Lee and others 2005).

areas within its flight range, which could be tens of kilometers for a strong flier or under favorable weather conditions (Dingle 1972, Pedgley 1993). To highlight the elevated risk of introduction in forested areas proximal to ports, U.S. ecoregion sections (Cleland and others 2005) were ranked according to the percentage of their total forested area that fell within a 160-km (100-mile) buffer around one of the ports identified by tonnage analysis. Susceptible forest areas were determined by intersecting the buffer with a forest distribution map developed from Moderate Resolution Imaging Spectoradiometer (MODIS) satellite imagery (250 m spatial resolution).

What Do the Data Show?

Between 1997 and 2004, 171 ports in the conterminous United States (fig. 7.1) received some tonnage of high-risk commodities. Two neighboring California ports (Los Angeles and Long Beach) had the highest total tonnages by a large margin, together receiving more than 270 million tons (table 7.3). When combined, the two biggest ports in the State of Washington (Seattle and Tacoma) received more than 82 million tons, somewhat less than the amount received at the port area of New York City[1] (approximately 89 million tons). Three ports clustered on the Southeastern United States coast—Charleston, SC; Savannah, GA; and Jacksonville, FL—ranked among the top 15 ports in the country. The Gulf of Mexico has several closely spaced ports, including several in the vicinity of the major ports of Houston, TX, and New Orleans, LA. No ports of the Great Lakes region ranked among the highest in tonnage, but the region has numerous, closely spaced ports that accepted low-to-moderate tonnages between 1997 and 2004.

For the five example insects (fig. 7.1), there appears to be strong correspondence between insect spatial distribution and marine port proximity. Only the distribution of the Mediterranean pine engraver does not directly overlap a major U.S. marine port or adjacent urban area. While this pest may have been introduced to the area by a different pathway, e.g., air cargo, several major marine ports are nearby, especially in the Los Angeles area, and the pest has commonly been intercepted from solid wood packing materials at U.S. marine ports (Lee and others 2005). Notably, these pests are emblematic of other recent invaders; for example, the Mediterranean pine engraver is

[1] Tonnage for New York City actually includes the total tonnage for port facilities in the New York City boroughs as well as ports across the Hudson River in New Jersey.

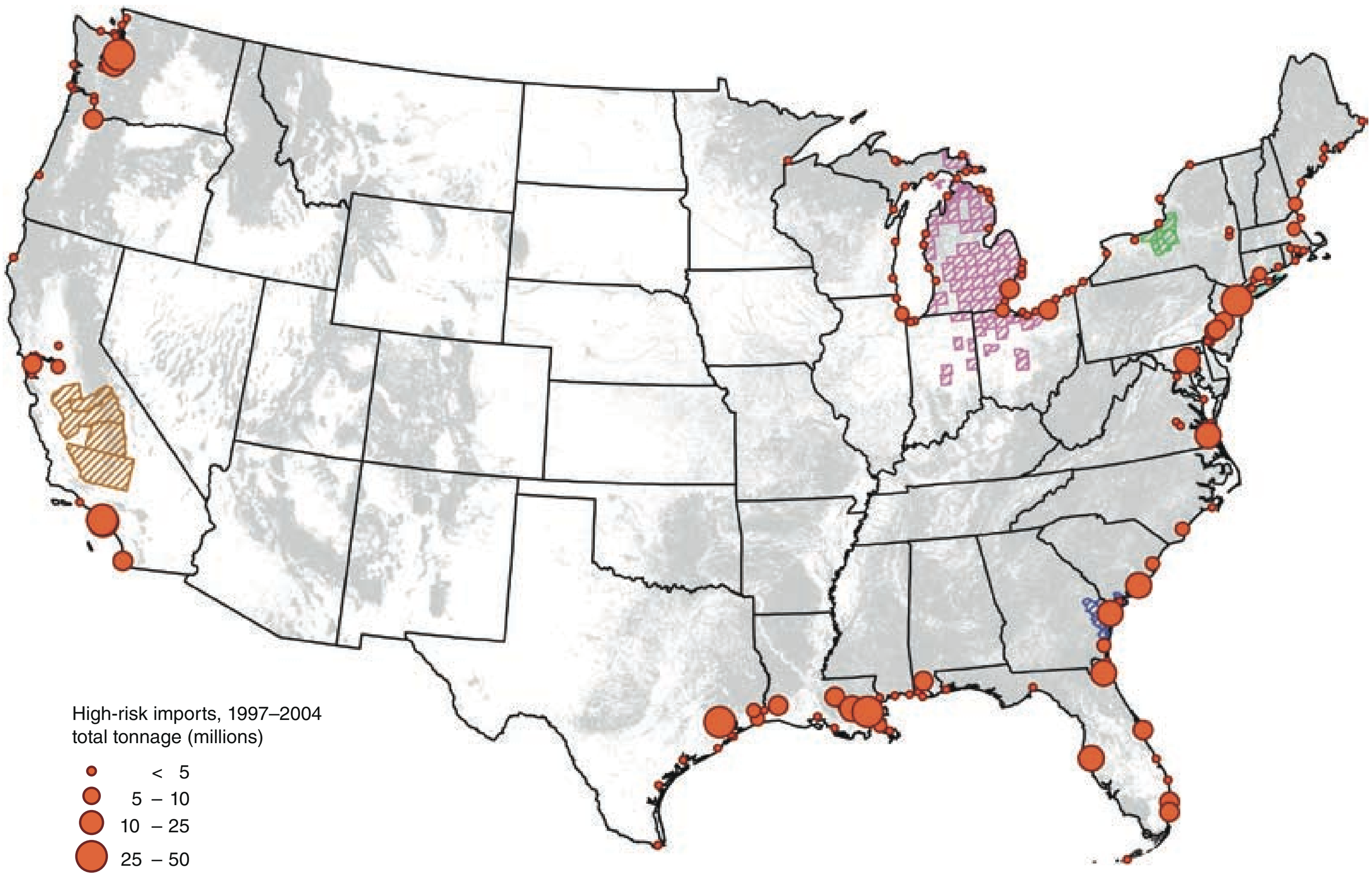

Figure 7.1—United States marine ports of entry ranked by tonnage of high-risk imports, combined with the spatial distribution of five forest insect pests. (County-level insect spatial data sources: asian longhorned beetle, http://ceris.purdue.edu/napis/maps/pstsurvey.html; redbay ambrosia beetle, Florida Department of Agriculture and Consumer Services, Forestry Division, and the Georgia Forestry Commission; emerald ash borer, http://eabviewer.rsgis.msu.edu/viewer.htm; sirex woodwasp, New York State Department of Agriculture and Markets, Division of Plant Industry; Mediterranean pine engraver, U.S. Department of Agriculture Forest Service. Forest cover source was the U.S. Department of Agriculture Forest Service, Remote Sensing Applications Center. Additional data source: U.S. Department of Transportation, Bureau of Transportation Statistics)

Table 7.3—Top 15 U.S. ports in terms of total tonnage of high-risk imports (1997–2004)[a]

Port	Tonnage
	short tons
Long Beach, CA	137,358,748
Los Angeles, CA	133,026,491
Houston, TX	90,569,953
New York, NY, and NJ	89,073,733
New Orleans, LA	70,462,491
Seattle, WA	55,151,673
Charleston, SC	48,358,707
Baltimore, MD	44,666,152
Savannah, GA	38,998,758
Port of South Louisiana, LA	35,981,554
Norfolk Harbor, VA	32,282,798
Jacksonville, FL	28,455,220
Tacoma, WA	26,988,061
Tampa, FL	25,160,558
Philadelphia, PA	23,691,829

[a]High-risk commodity categories were identified based on the types of cargo associated with forest insects in the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Port Information Network database: forest products or commodities that are typically shipped with wood packaging (table 7.1).

one of four new bark beetle species believed to have been established in the United States since 2000 (Haack 2006).

Certain regions are of particular concern because of the large proportion of potentially susceptible forest within a short distance of high-tonnage marine ports. Of the 190 ecoregion sections in the conterminous United States, 37 had more than 95 percent of their forested area within 160 km (100 miles) of a marine port of entry (fig. 7.2). On the Pacific Coast, these included a heavily forested section, M242A—Oregon and Washington Coast Ranges, as well as two sparsely forested sections, 261B—Southern California Coast and M262B—Southern California Mountain and Valley. All of the ecoregion sections surrounding Lake Michigan fell mostly within the buffer zone. These sections include three heavily forested ones: 212S—Northern Upper Peninsula, 212R—Eastern Upper Peninsula, and 212H—Northern Lower Peninsula. In New England, most ecoregion sections had more than 60 percent of their forested area with 100 miles of a high-risk port. In the Southeast, the heavily forested 232C—Atlantic Coastal Flatwoods section may face

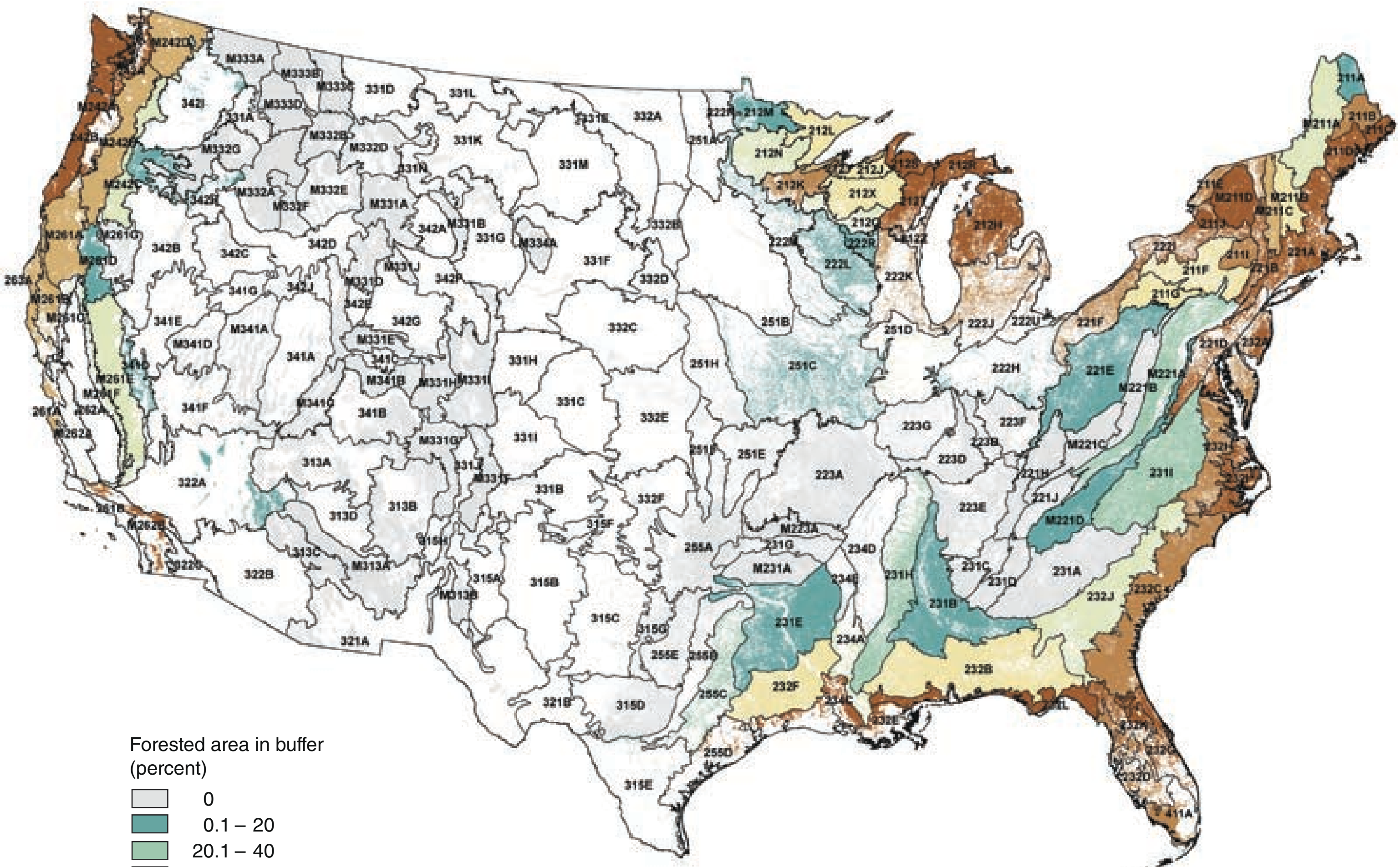

Figure 7.2—U.S. ecoregion sections ranked by the percentage of their forested area that falls within 160 km (100 miles) of a marine port of entry. Gray lines are ecoregion sections (Cleland and others 2005.) Forest cover source was the U.S. Department of Agriculture Forest Service, Remote Sensing Applications Center. (Port location data sources: U.S. Army Corps of Engineers, Navigation Data Center; U.S. Department of Commerce, Bureau of Transportation Statistics)

particularly severe risk, with the combination of three major ports (Charleston, Savannah, and Jacksonville), several minor ports, and climatic conditions that are suitable for insect pest persistence. Another section, 232L—Gulf Coastal Lowlands, may face a similar threat level.

As noted, several assumptions about what should be considered high risk must be made when using these data. For example, the limited thematic resolution of the data, i.e., a lack of specific categories for nursery stock or other live plant material, did not permit assessment of forest pathogen introduction risk as distinct from insect pest risk. More generally, the marine port data presented here are only a part of the total forest pest risk from international trade. Similar datasets are available for land border crossings, airports, and ports along inland waterways of the United States, so a fuller examination would reconcile these datasets with the marine cargo data to create a more comprehensive national picture. It is also important to note that this analysis did not address the role of domestic transport of commodities after they are received at U.S. marine ports. While it may appear that the greatest risk of forest pest introductions is associated with areas relatively close to marine ports, individual cargo shipments may travel long distances. Indeed, although more than 55 percent of marine cargo tonnage imported into the United States in 2002 remained in the same statistical region as the port of entry, approximately 14 percent of the nation's freight tonnage in 2002, regardless of origin, traveled distances of 500 miles or more (U.S. Department of Transportation, Bureau of Transportation Statistics; U.S. Department of Commerce, U.S. Census Bureau 2005) (U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations 2006). For example, the banded elm bark beetle, first detected in baited traps in Colorado and Utah in 2003 but since found extensively throughout the Intermountain West (fig. 7.3), may have been introduced via this kind of long-distance shipment (Lee and others 2006, Liu and Haack 2003). Essentially, since a single infested cargo shipment may potentially result in a specific pest's introduction, and given the nation's well-developed transportation infrastructure, virtually every forested location in the conterminous United States faces some risk from pests introduced by international trade.

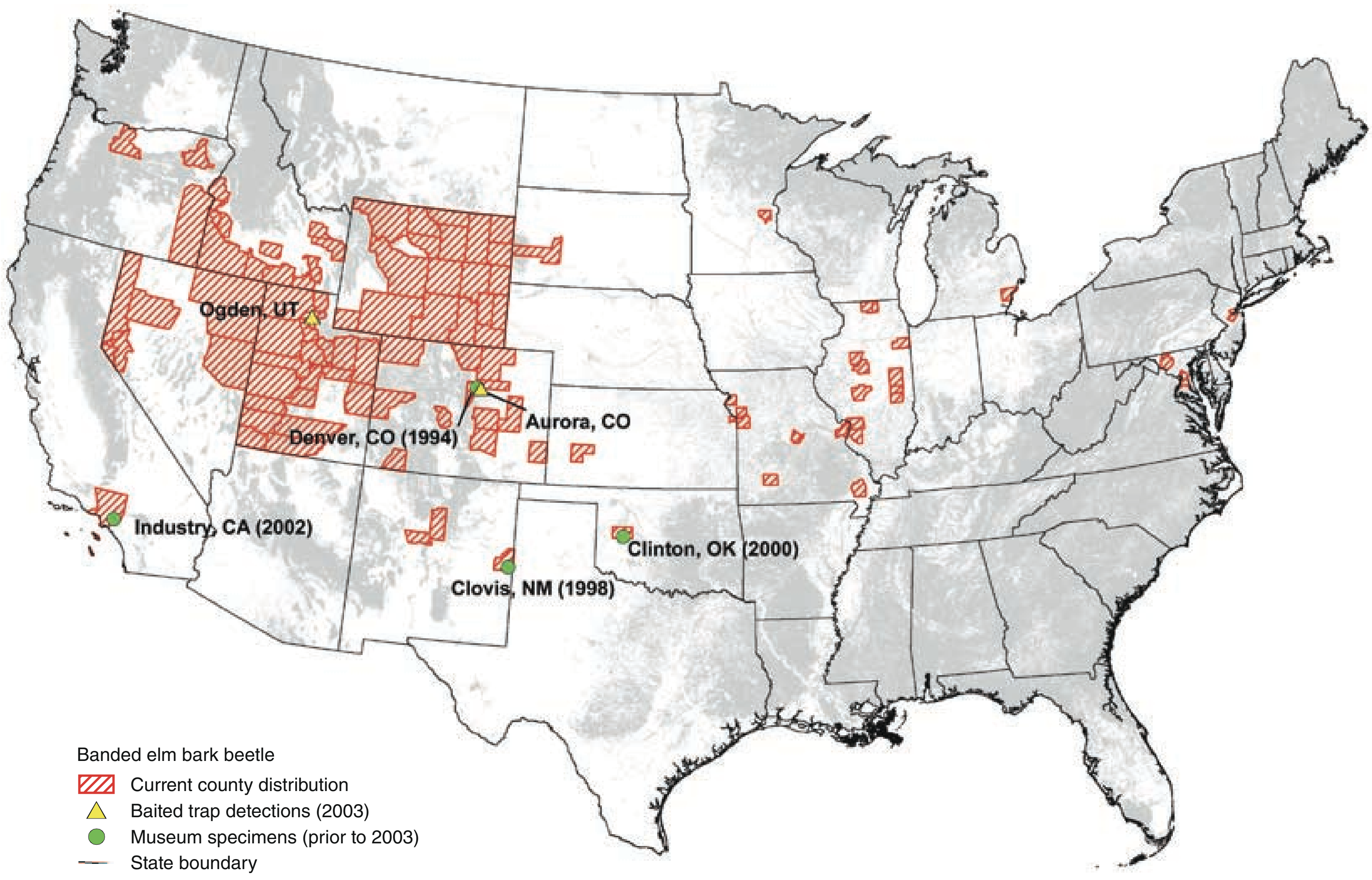

Figure 7.3—Current county-level distribution of the banded elm bark beetle, Scolytus schevyrewi. *Although first detected in baited traps in 2003, museum specimens suggest that the pest was likely introduced to the Intermountain West region by the early 1990s. Forest cover source was the U.S. Department of Agriculture Forest Service, Remote Sensing Applications Center. [Distribution data source: U.S. Department of Agriculture Forest Service, Alien Forest Pest Explorer, http://www.fs.fed.us/ne/morgantown/4557/AFPE/data.html. Locations of the first trap detections, as well as museum specimens collected prior to 2003, were reported in Lee and others (2006)]*

Treatment of wood packaging materials could greatly reduce the risk of pest introductions. In 2004, the U.S. Department of Agriculture issued a rule requiring heat treatment or fumigation of wood packaging materials for cargo imported into the United States, but such practices have not yet been standardized worldwide, and will not eliminate all introduction risk (Haack 2006) [U.S. Department of Agriculture, Animal and Plant Health Inspection Service. 7 CFR Part 319 – importation of wood packaging materials. Federal Register 69(179): 55 719–55 733 (16 September 2004)]. In the meantime, increased monitoring in high-risk forested areas may catch pests before they become established problems, thus substantially reducing control costs. This is consistent with the observations of a recent U.S. Government Accountability Office (2006) report on forest pests, which advocates increased systematic monitoring of urban forests, particularly in port cities.

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