CRITERION 3—

Chapter 5. Large-Scale Patterns of Insect and Disease Activity in the Conterminous United States and Alaska, 2006

Kevin M. Potter[1]

Frank H. Koch

Introduction

Analyzing patterns of forest pest infestation is necessary for monitoring the health of forested ecosystems because of the impact insects and diseases can have on forest structure and composition, biodiversity, and species distributions (Castello and others 1995). In particular, introduced nonnative insects and diseases can extensively damage the diversity, ecology, and economy of affected areas (Brockerhoff and others 2006, Mack and others 2000). Examining pest occurrences from a landscape-scale perspective is useful, given the regional extent of many infestations and the interaction between landscape patterns and the development of pest outbreaks (Holdenrieder and others 2004). The detection of geographic clusters of disturbance is one such landscape-scale approach, which allows for the identification of areas at greatest risk of significant impact and for the selection of locations for more intensive analysis.

Methods

We used nationally compiled low-altitude aerial survey and ground survey data, collected by the Forest Health Protection (FHP) of the Forest Service, U.S. Department of Agriculture, from 2006 to identify landscape-scale hotspots of forest insect and disease activity in the conterminous 48 States, and to summarize insect and disease activity by ecoregion section in Alaska. Surveys in 2006 covered approximately 65 percent of the forested area in the conterminous United States and approximately 19 percent of Alaska's forested area (fig. 5.1). These surveys identify areas of mortality and defoliation caused by insect and pathogen activity. A pathogen or insect might be considered a mortality-causing agent in one location and a defoliation-causing agent in another, depending on the level of damage to the forest in a given area. Additionally, differences in data collection procedures among States and regions can complicate the analysis of the data and the interpretation of the results. Analysis of the survey data across multiple years is not appropriate in most situations because both the location and extent of the areas surveyed and the classification of forest tree mortality and defoliation agents varies across years.

We used a forest cover map (1-km^2 resolution) derived from Moderate Resolution Imaging Spectroradiometer imagery by the Forest Service, Remote Sensing Applications Center (U.S. Department of Agriculture Forest Service 2008) to determine the amount and location of forest within survey defoliation and mortality polygons. Areas reported here reflect polygons masked by forest cover.

[1] Corresponding author: Kevin M. Potter, Research Assistant Professor, North Carolina State University, Department of Forestry and Environmental Resources, Raleigh, NC 27695.

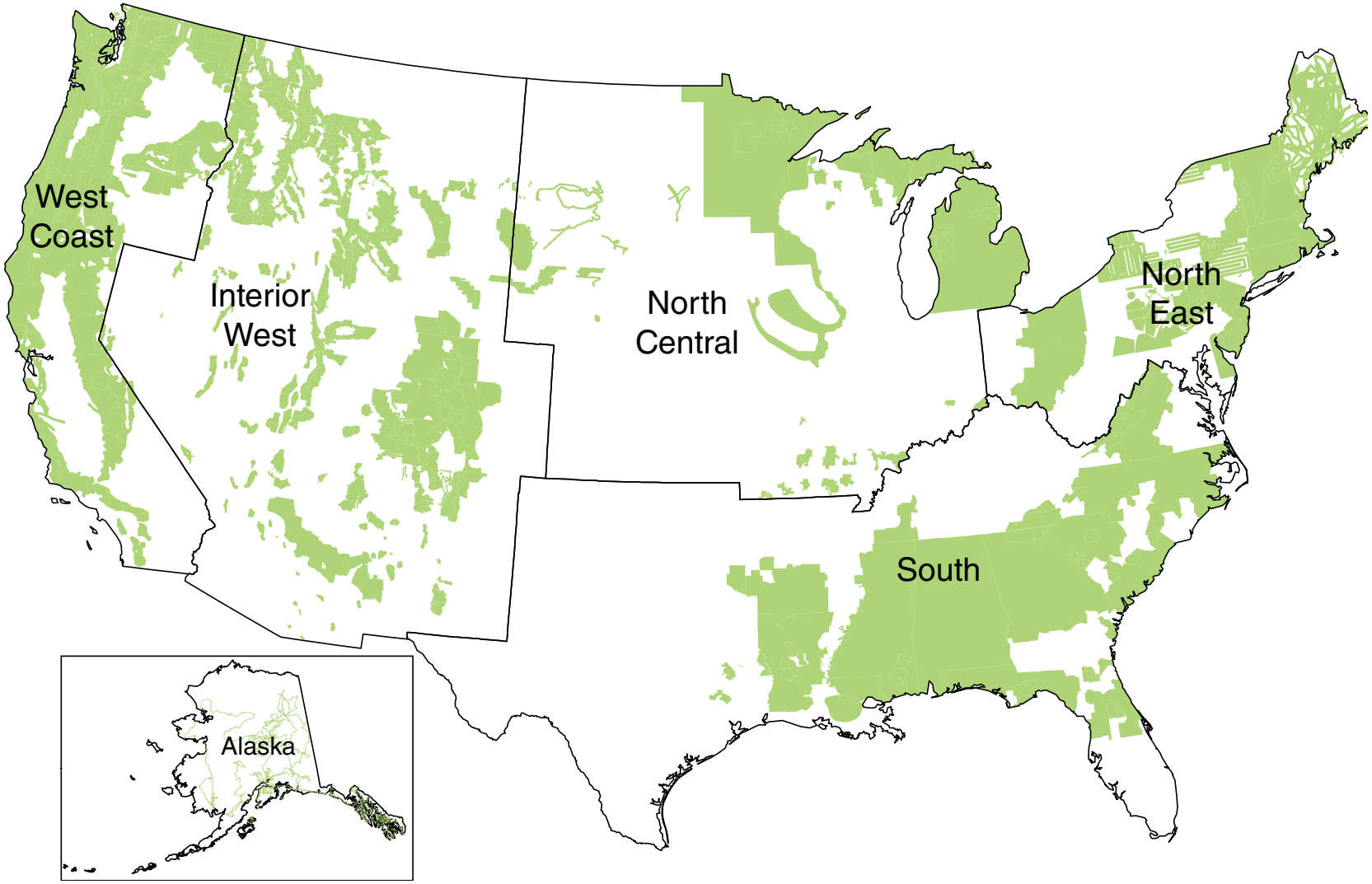

Figure 5.1—The extent of surveys for insect and disease activity conducted in the conterminous United States and Alaska in 2006 (shown in green). The lines delineate FHM regions. (Data source: Forest Service, Forest Health Protection)

We employed a Getis-Ord hotspot analysis (Getis and Ord 1992) to identify forested areas with the greatest exposure to mortality-causing and defoliation-causing agents. We intensified the Environmental Monitoring and Assessment Program North American hexagon coordinates (White and others 1992) to develop a lattice of hexagonal cells, of approximately 2500-km^2 extent, for the conterminous United States. This cell size allows for analysis at a medium-scale resolution of approximately the same area as a county. We then calculated the percent of forest area in each hexagon exposed to either mortality- or defoliation-causing agents. The Getis-Ord G_i^* statistic summed the differences between the mean values in a local sample, determined by a moving window consisting of each hexagon and its six adjacent hexagons, and the global mean of all the forested hexagonal cells in the conterminous 48 States. G_i^* is standardized as a z score with a mean of zero and a standard deviation of 1, with values greater than approximately 2 representing strong and significant local clustering ($p < 0.025$) of high values, and values less than approximately -2 representing significant local clustering of low values ($p < 0.025$).

Polygons associated with two specific mortality agents required additional processing because the data were reported at a coarser resolution than for the other agents. First, a single polygon classified approximately 4.25 million ha of land area (including 900 000 ha of forest) in southeastern Michigan as experiencing emerald ash borer (*Agrilus planipennis*) mortality in 2006. We calculated overall ash mortality across the area as 13.3 percent, by multiplying the mortality rate (24.2 percent) by the percent of forest containing ash (*Fraxinus* spp.). We assumed that 55 percent of the forest in this area contained ash, because ash species occurred on 55 percent of the 1,120 Forest Inventory and Analysis plots within the area. We also assumed that ash experienced 24.2 percent mortality from emerald ash borer across the area, based on data collected in 2005 from 20 sites in southeastern Michigan (Witter and others 2006).

A second set of polygons, based on ground surveys by the Maine Forest Service, delineated an area of 2.9 million ha in eastern Maine experiencing fir mortality following balsam woolly adelgid (*Adelges piceae*) infestation. This area was divided into three tiers according to degree of fir mortality, with firs experiencing 24 percent mortality in the tier closest to the coast, 5 percent mortality in the next tier inland, and 1 percent mortality in the third inland tier (Laustsen 2006). We estimated the extent and location of mortality caused by the balsam woolly adelgid by multiplying mortality within each tier by the amount of forest in the spruce/fir forest-type group (U.S. Department of Agriculture Forest Service 2008). Spruce/fir forest covered 45 percent of the overall delineated area.

Results and Discussion

The 2006 FHP aerial survey data identified 48 different biotic mortality-causing agents on 2 420 298 ha of forest across the conterminous United States, an area slightly smaller in extent than that of the commonwealth of Massachusetts. It is also slightly larger than the approximately 2.14 million ha of tree mortality estimated by the 2006 FHP report on forest insect and disease conditions in the United States (U.S. Department of Agriculture Forest Service 2007), which did not include the "sparse mortality" polygons for emerald ash borer in Michigan and balsam woolly adelgid in Maine. The mortality agents with the most widespread occurrence were mountain pine beetle (*Dendroctonus ponderosae*) (1 010 365 ha), emerald ash borer (504 964 ha), and balsam woolly adelgid (138 490 ha). Also in 2006, the survey identified 51 biotic defoliation agents affecting approximately 2 765 232 ha of forest across the conterminous United States, an area slightly larger than Massachusetts, with the largest areas exposed to defoliation by forest tent caterpillar (*Malacosoma disstria*) (960 986 ha), western spruce budworm (*Choristoneura occidentalis*) (787 282 ha), and gypsy moth (*Lymantria dispar*) (449 098 ha). The defoliation area estimates for these three pests are similar to those in the 2006 forest insect and disease conditions report (U.S. Department of Agriculture Forest Service 2007): 1 076 760 ha for forest tent caterpillar, 939 680 ha for western spruce budworm (an increase from 488 051 ha in 2005), and 522 044 ha for gypsy moth (an increase from 271 139 ha the previous year). For the mortality agents with the most widespread occurrence in the survey data, the forest insect disease conditions report estimated that approximately 1.17 million ha experienced mountain pine beetle mortality, but did not estimate the extent of mortality for emerald ash borer and balsam woolly adelgid.

Our national-scale hotspot analysis detected three hotspots of insect and disease mortality in the eastern two-thirds of the country, and approximately a dozen in the West (fig. 5.2A). Two of the largest eastern hotspots were associated with emerald ash borer and balsam woolly adelgid, despite our adjustments to the initial coarse-scale delineation of the extent of these mortality agents. The largest of the three eastern hotspots was located in the northern Midwest, where exposure to emerald ash borer created a mortality hotspot in the lower peninsula of Michigan. In the Northeast, balsam woolly adelgid mortality was reported across the forested areas of coastal Maine. A third, smaller mortality hotspot occurred in the Western Great Plains (ecoregion section 331F) in southwestern South Dakota and northwestern Nebraska, where pine engraver beetles (*Ips* spp.) represented an agent of mortality across the scattered ponderosa pine (*P. ponderosa*) forest.

Mountain pine beetle was the predominant agent associated with several mortality hotspots in the Interior West (fig. 5.2A). The most highly clustered of these hotspots occurred in northern Colorado and southern Wyoming. Here, spruce beetle (*Dendroctonus rufipennis*), subalpine fir (*Abies lasiocarpa*) mortality, pine engraver, Douglas-fir beetle (*Dendroctonus pseudotsugae*), and five-needle pine decline also contributed to mortality exposure. One hotspot in the Uinta Mountains (M331E) of northeastern Utah was caused mostly by mountain pine beetle, while another, smaller hotspot in the White Mountains-San Francisco Peaks area of southwestern New Mexico (M313A) was associated with western pine beetle (*Dendroctonus brevicomis)*.

Further north, mountain pine beetle also accounted for most mortality-causing activity in a large complex of hotspots in Montana, Idaho, and Wyoming (fig. 5.2A). Western balsam bark beetle (*Dryocoetes confusus*) and Douglas-fir beetle also contributed significantly to mortality in this area. Subalpine fir decline and spruce beetle caused a separate and smaller hotspot in the nearby Bighorn Mountains of north central Wyoming.

Mountain pine beetle and western pine beetle were important factors in two mortality hotspots near the west coast (fig. 5.2A). One of these extended along the Cascade Mountains from northcentral Washington to southcentral Oregon. In nearby northeastern Washington, another mountain pine beetle hotspot was located in the Okanogan Highland area (M333A). Fir engraver beetle (*Scolytus ventralis*), spruce beetle, and Douglas-fir beetle also contributed to mortality in the area.

A smaller hotspot along the southern coast of Oregon (fig. 5.2A) was caused primarily by Port-Orford-cedar root disease (caused by *Phytophthora lateralis*), along with the flatheaded borer (family *Buprestidae*), pine engraver, fir engraver, mountain pine beetle, and Douglas-fir beetle. Additionally, a single-hexagon hotspot in the Sierra Nevada of California (M261E) was associated with bark beetles and fir engraver.

Our analysis also detected six hotspots of 2006 defoliation activity (fig. 5.2B). The most extensive of these were in the Northeast, where the close proximity of two centers of high defoliation activity, associated mostly with forest tent caterpillar and gypsy moth, resulted in a single large hotspot. The eastern center of activity, in Lower New England (221A), included defoliation by forest tent caterpillar, gypsy moth, Nantucket pine tip moth (*Rhyacionia frustrana*), pine needleminer (*Exoteleia pinifoliella*), fall cankerworm (*Alsophila pometaria*), winter moth (*Operophtera brumata*), and orangestriped oakworm (*Anisota senatoria*). The western center of defoliation activity encompassed portions of southeastern New York and northeastern Pennsylvania. Defoliation here was caused by forest tent caterpillar, gypsy moth, and locust leafminer (*Odontota dorsalis*). The Northeast

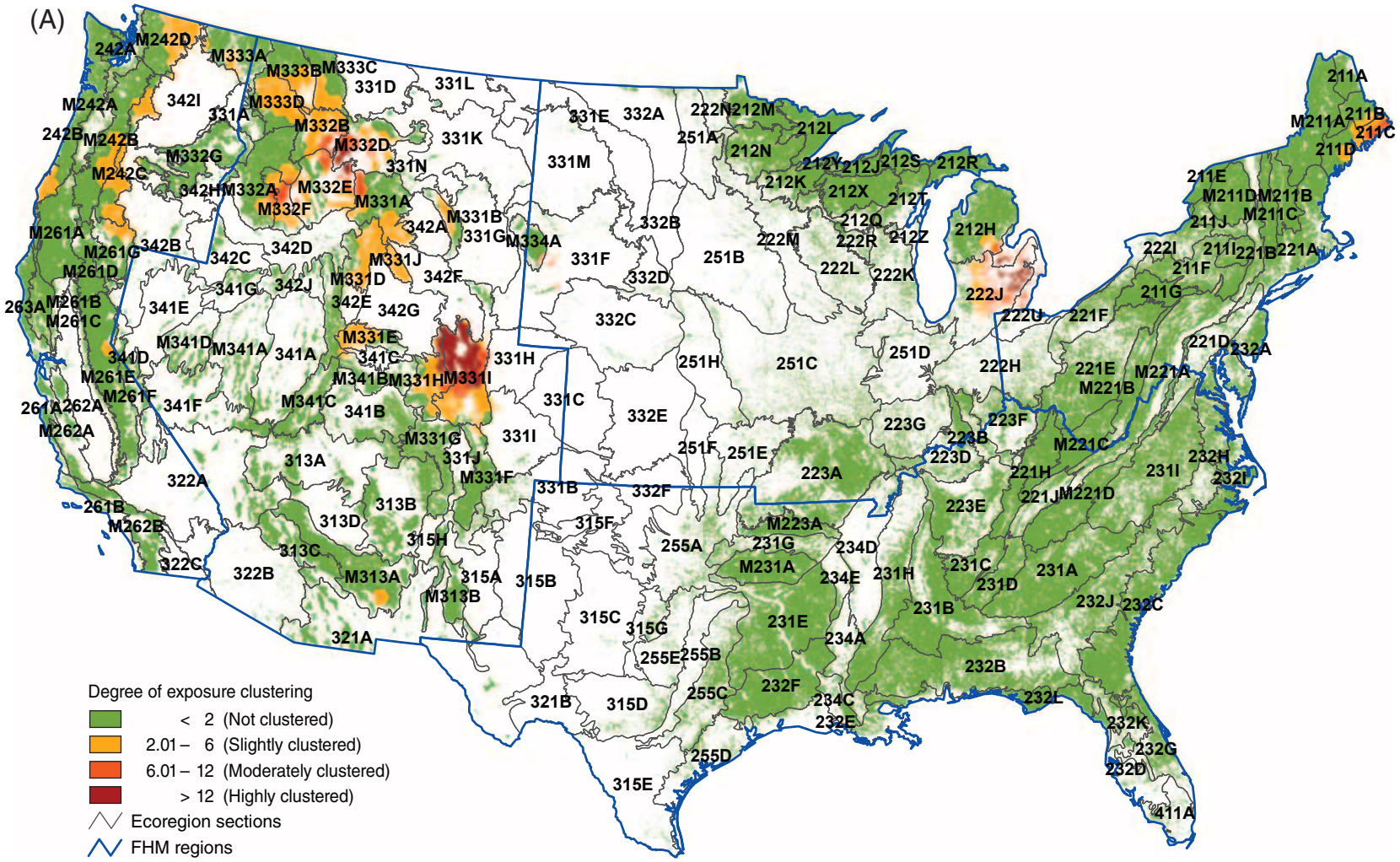

Figure 5.2—Hotspots of exposure to (A) mortality-causing insects and diseases and (B) defoliation-causing insects and diseases in 2006. Values are Getis-Ord G_i scores, with values > 2 representing strong and significant clustering of high percentages of forest exposed to damaging agents. The gray lines delineate ecoregion sections (Cleland and others 2007). Background forest cover is derived from MODIS imagery by the Forest Service, Remote Sensing Applications Center. (Data source: Forest Service, Forest Health Protection)* *(continued on next page)*

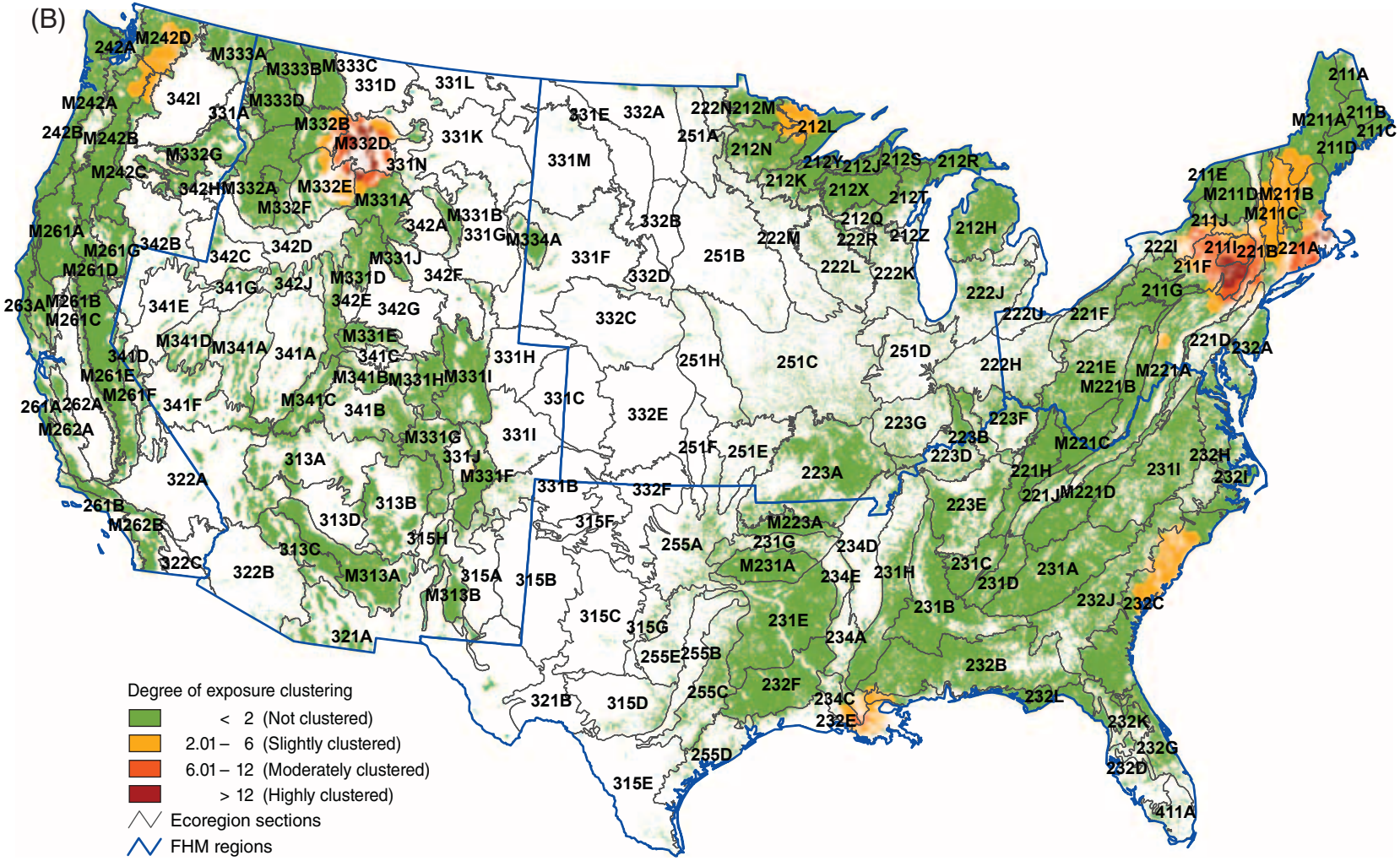

Figure 5.2 (continued)—Hotspots of exposure to (A) mortality-causing insects and diseases and (B) defoliation-causing insects and diseases in 2006. Values are Getis-Ord G_i scores, with values > 2 representing strong and significant clustering of high percentages of forest exposed to damaging agents. The gray lines delineate ecoregion sections (Cleland and others 2007). Background forest cover is derived from MODIS imagery by the Forest Service, Remote Sensing Applications Center. (Data source: Forest Service, Forest Health Protection)*

hotspot extended north into Vermont, New Hampshire, and western Maine, where defoliation was caused by forest tent caterpillar, hardwood anthracnose (*Kabatiella apocrypta*), Septoria leaf spot (*Septoria alnifolia*), saddled prominent caterpillar (*Heterocampa guttivitta*), and birch leafminer (*Fenusa pusilla*).

Forest tent caterpillar also was associated with two defoliation hotspots in the South, one in coastal South Carolina and southeastern North Carolina, and the other encompassing southeastern Louisiana (fig. 5.2B). Baldcypress leafroller (*Archips goyerana*) was also an important defoliating insect in the latter hotspot.

Western spruce budworm was responsible for two hotspots of defoliation exposure in the West (fig. 5.2B). The more concentrated defoliation activity occurred in the Interior West, in southwestern Montana. A less concentrated hotspot on the west coast stretched across the Cascades. Black pineleaf scale (*Nuculaspis californica*) and needlecast also caused defoliation in this area.

A defoliation hotspot in northern Minnesota (fig. 5.2B), meanwhile, was associated primarily with spruce budworm and jack pine budworm (*Choristoneura pinus*), with smaller amounts of eastern larch beetle (*Dendroctonus simplex*) and larch casebearer (*Coleophora laricella*).

The low density of aerial survey data from Alaska in 2006 precluded the use of hotspot analyses for that State. Instead, mortality and defoliation data were summarized by ecoregion section. Four mortality-causing agents were reported for Alaska, affecting 65 913 ha, which represented <1 percent of the forest surveyed (9.69 million ha). Spruce beetle had the largest extent, detected on 48 417 ha, mostly in the Northern Aleutian Range (M213A). This section also had the highest percent of exposure to forest mortality agents at 12.25 percent (fig. 5.3A), although forest in this section is fairly limited in extent. Two nearby ecoregion sections—the Bristol Bay Lowlands (213A) and the Ahklun Mountains (M129B)—also experienced a somewhat high amount of forest mortality (5.85 and 1.37 percent of total forest area exposed to mortality, respectively) as a result of the spruce beetle. Other more heavily forested ecoregion sections experienced <1 percent exposure to agents of forest mortality. Other causes of mortality were Alaska yellow-cedar (*Chamaecyparis nootkatensis*) decline, recorded on 12 849 ha, northern spruce engraver beetle (*Ips perturbatus*) (4433 ha), bark beetle (201 ha), and larch beetle (13 ha).

Alaska forests, meanwhile, were exposed to 13 defoliation agents recorded on 281 310 ha, or 2.9 percent of the surveyed forest area. Aspen leafminer (*Phyllocnistis populiella*) had by far the largest extent, observed on 185 306 ha across eastcentral Alaska. As a result of aspen leafminer, five ecoregion sections had relatively high percentages of exposure to forest defoliation agents (1 to 2 percent): the Yukon Bottomlands (131A), the Kuskokwin Colluvial Plain (131B), the Copper River Basin (135A), the Yukon Flats (139A), and the Dawson Range (M139C) (fig. 5.3B).

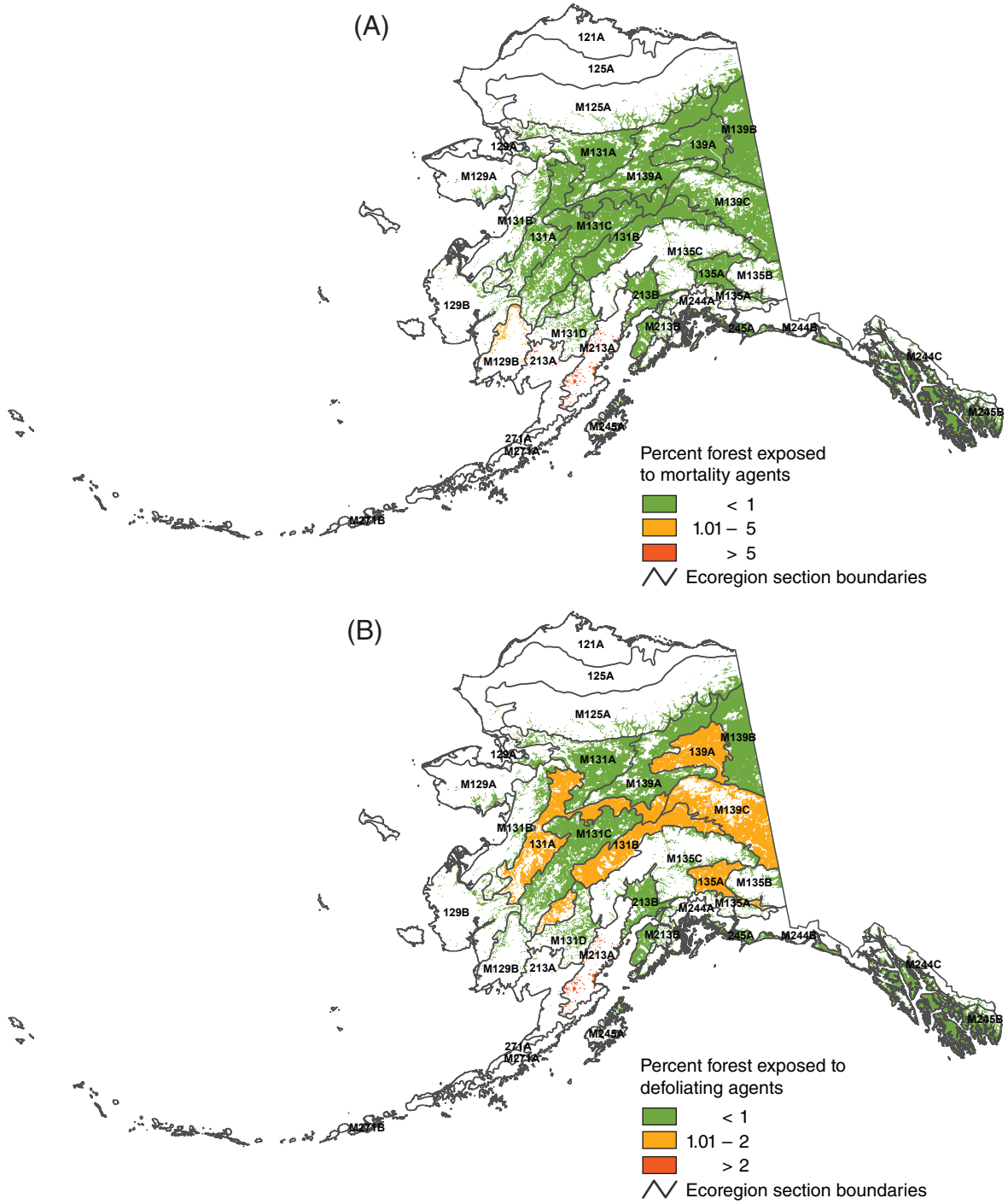

Figure 5.3—Percent of forest in Alaska ecoregion sections (Nowacki and Brock 1995) exposed to (A) mortality-causing insects and diseases and (B) defoliation-causing insects and diseases in 2006. Background forest cover is derived from MODIS imagery by the Forest Service, Remote Sensing Applications Center. (Data source: Forest Service, Forest Health Protection)

Other important defoliators in Alaska were spruce budworm (21 521 ha), willow leafblotch miner (*Micrurapteryx salicifoliella*) (20 471 ha), and large aspen tortrix (*Choristoneura conflictana*) (13 934 ha). The Northern Aleutian Range (M213A) had the greatest observed defoliation, with 2.4 percent of its forest exposed to defoliation by a hardwood skeletonizer, but only a small proportion (6.3 percent or 233 832 ha) of the section is forested.

Continued monitoring of these insect and disease outbreaks in the conterminous 48 States and Alaska will be necessary to determine appropriate followup investigation and management activities. As this analysis of mortality and defoliation exposure demonstrates, hotspot detection can help prioritize geographic areas where the concentration of these activities would be most useful.

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