CHAPTER 2.

Large-Scale Patterns of Insect and Disease Activity in the Conterminous United States and Alaska from the National Insect and Disease Survey, 2011

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INTRODUCTION

The impacts of insects and pathogens on forests vary from natural thinning to extraordinary levels of tree mortality, but the fact that insects and diseases kill trees does not necessarily make them enemies of the forest (Teale and Castello 2011). If disturbances, pests, and diseases are viewed in their full ecological context, then some amount can be considered "healthy" to sustain the structure of the forest (Manion 2003, Zhang and others 2011) by causing the tree mortality that culls weak competitors and releases resources that are needed to support the growth of the surviving trees (Teale and Castello 2011).

Recognizing how much mortality is natural, and how much is excessive, is an important task for forest managers, pathologists, and entomologists, and relates to ecologically based or commodity-based management objectives (Teale and Castello 2011). Diseases and insects cause changes in forest structure and function, species succession, and biodiversity, which may be considered negative or positive depending on management objectives (Edmonds and others 2011).

Analyzing patterns of forest pest infestations, disease occurrences, forest declines, and related biotic stress factors is necessary to monitor the health of forested ecosystems and their potential impacts on forest structure, composition, biodiversity, and species distributions (Castello and others 1995). Introduced nonnative insects and diseases, in particular, can extensively damage the diversity, ecology, and economy of affected areas (Brockerhoff and others 2006, Mack and others 2000). Few forests remain unaffected by invasive species, and their devastating impacts in forests are undeniable, including, in some cases, wholesale changes to the structure and function of an ecosystem (Parry and Teale 2011).

Examining pest occurrences and related stress factors from a landscape-scale perspective is useful, given the regional extent of many infestations and the large-scale complexity of interactions among host distribution, stress factors, and the development of pest outbreaks (Holdenrieder and others 2004). The detection of geographic clusters of disturbance is one such landscape-scale approach that allows for the identification of areas at greater risk of significant impact and for the selection of locations for more intensive monitoring and analysis.

METHODS

Nationally compiled Forest Health Protection (FHP) low-altitude aerial survey and ground survey data (FHM 2005) can be used to identify forest landscape-scale patterns associated with geographic hot spots of forest insect and disease activity in the conterminous 48 States and to summarize insect and disease activity by ecoregion in Alaska (Potter and Koch 2012, Potter 2012, Potter 2013, Potter and Paschke 2013). In 2011, FHP surveys covered approximately 147.9 million ha of the forested area in the conterminous United States

(58 percent of the total), and 8.0 million ha of Alaska's forested area (15.6 percent of the total) (fig. 2.1).

These surveys identify areas of mortality and defoliation caused by insect and pathogen activity, although some important forest insects (such as emerald ash borer and hemlock woolly adelgid), diseases (such as laurel wilt, Dutch elm disease, white pine blister rust, and thousand cankers disease), and mortality complexes (such as oak decline) are not easily detected or thoroughly quantified through aerial detection surveys. Such pests may attack hosts that are widely dispersed throughout forests with high tree species diversity or may cause mortality or defoliation that is otherwise difficult to detect. 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 and the convergence of stress factors such as drought. In some cases, the identified agents of mortality or defoliation are actually complexes of multiple agents summarized under an impact label related to a specific host tree species (e.g., "subalpine fir mortality" or "aspen defoliation"). In addition, differences in data collection, attribute recognition, and coding procedures among States and regions can complicate the analysis of the data and the interpretation of the results.

The 2011 mortality and defoliation polygons were used to identify the mortality and defoliation agents and complexes found on more than 5000 ha of forest in the conterminous United States in that year and to identify and list the most widely detected defoliation and mortality agents for Alaska. As a result of the insect and disease sketch-mapping process, all quantities are "footprint" areas for the agent or complex, outlining the areas within which the agent or complex is present. Unaffected trees may exist within the footprint, and the amount of damage within the footprint is not reflected in the estimates of forest area affected. The sum of agents and complexes is not equal to the total affected area as a result of reporting multiple agents per polygon in some situations.

A Getis-Ord hot spot analysis (Getis and Ord 1992) was employed in ArcMap 9.2 (ESRI 2006) to identify surveyed forest areas with the greatest exposure to the detected mortality- and defoliation-causing agents and complexes. The Environmental Monitoring and Assessment Program North American hexagon coordinates (White and others 1992) were intensified to develop a lattice of hexagonal cells, of 2500 km^2 extent, for the conterminous United States. This cell size allows for analysis at a medium-scale resolution of about the same area as a typical county. The percentage of surveyed forest area in each hexagon exposed to either mortality-causing or defoliation-causing agents was then calculated by masking the surveyed area and mortality and defoliation polygons with a forest cover map (1-km^2 resolution), derived from Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery by the Forest Service Remote Sensing Applications Center (USDA Forest Service 2008). The percentage

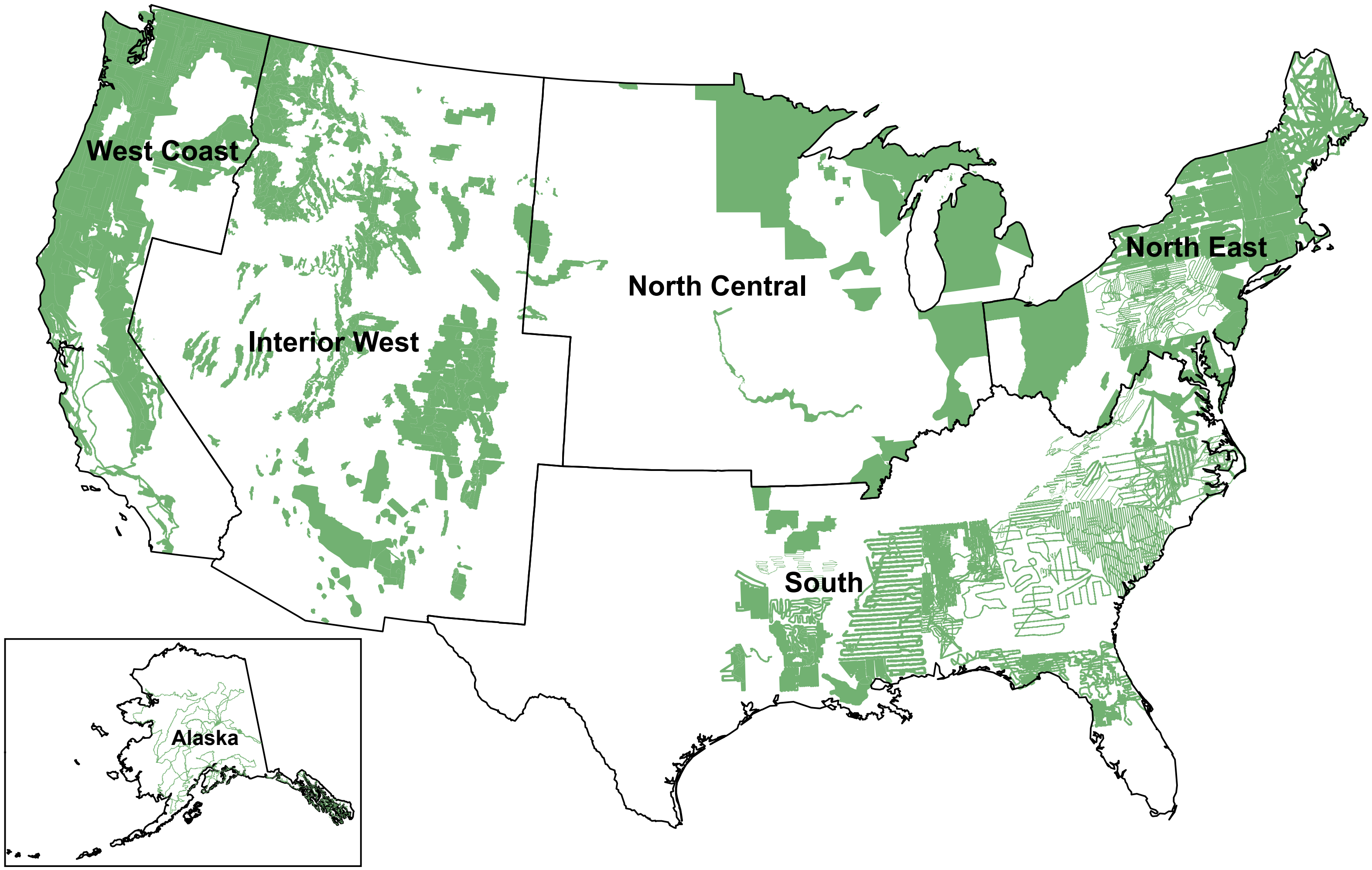

Figure 2.1—The extent of surveys for insect and disease activity conducted in the conterminous United States and Alaska in 2011. The black lines delineate Forest Health Monitoring regions. (Data source: USDA Forest Service, Forest Health Protection Program.)

of surveyed forest exposed to mortality or defoliation agents was calculated by dividing the total forest-masked damage area by the forest-masked surveyed area.

The Getis-Ord G_i* statistic was used to identify clusters of hexagonal cells in which the percentage of surveyed forest exposed to mortality or defoliation agents was higher than expected by chance. This statistic allows for the decomposition of a global measure of spatial association into its contributing factors, by location, and is therefore particularly suitable for detecting nonstationarities in a dataset, such as when spatial clustering is concentrated in one subregion of the data (Anselin 1992).

The Getis-Ord G_i* statistic for each hexagon summed the differences between the mean values in a local sample, determined by a moving window consisting of each hexagon and its 18 first- and second-order neighbors (the 6 adjacent hexagons and the 12 additional hexagons contiguous to those 6), and the global mean of all the forested hexagonal cells in the conterminous 48 States. It is then standardized as a *z*-score with a mean of 0 and a standard deviation of 1, with values greater than 1.96 representing significant ($p < 0.025$) local clustering of high values and values less than -1.96 representing significant clustering of low values ($p < 0.025$), because 95 percent of the observations under a normal distribution should be within approximately 2 standard deviations of the mean (Laffan 2006). In other words, a G_i* value of 1.96 indicates that the local mean of the percentage of forest exposed to mortality- or defoliation-causing agents for a hexagon and its 18 neighbors is approximately 2 standard deviations greater than the mean expected in the absence of spatial clustering, whereas a G_i* value of -1.96 indicates that the local mortality or defoliation mean for a hexagon and its 18 neighbors is approximately 2 standard deviations less than the mean expected in the absence of spatial clustering. Values between -1.96 and 1.96 have no statistically significant concentration of high or low values. In other words, when a hexagon has a G_i* value between -1.96 and 1.96, it and its 18 neighbors have neither consistently high nor consistently low percentages of forest exposed to mortality- or defoliation-causing agents.

It is worth noting that the threshold values are not exact because the correlation of spatial data violates the assumption of independence required for statistical significance (Laffan 2006). The Getis-Ord approach does not require that the input data be normally distributed because the local G_i* values are computed under a randomization assumption, with G_i* equating to a standardized *z*-score that asymptotically tends to a normal distribution (Anselin 1992). The *z*-scores are reliable, even with skewed data, as long as the distance band used to define the local sample around the target observation is large enough to include several neighbors for each feature (ESRI 2006).

The low density of survey data from Alaska in 2011 (fig. 2.1) precluded the use of hot spot analyses for the State. Instead, mortality and defoliation data were summarized by ecoregion section (Nowacki and Brock 1995), calculated as the percentage of the forest within the surveyed areas affected by agents of mortality or defoliation. For reference purposes, ecoregion sections (Cleland and others 2007) were also displayed on the geographic hot spot maps of the conterminous 48 States.

RESULTS AND DISCUSSION

The FHP survey data identified 78 different mortality-causing agents on approximately 2.26 million ha across the conterminous United States in 2011, an area slightly larger than that of the combined land area of New Jersey and Rhode Island. (Of these mortality-cause categories, three were "rollups" of multiple agents.) By way of comparison, forests cover about 304 million ha of the conterminous 48 States (Smith and others 2009).

Mountain pine beetle (*Dendroctonus ponderosae*) was the most widespread mortality agent, detected on 1.54 million ha (table 2.1). Other mortality agents and complexes detected across very large areas, each affecting more than 100 000 ha, were five-needle pine decline, spruce beetle (*D. rufipennis*), fir engraver (*Scolytus ventralis*), and subalpine fir (*Abies lasiocarpa*) mortality. Mortality from the western bark beetle group, encompassing 19 different agents in the insect and disease survey data (table 2.2), was detected on a total of more than 2.12 million ha in 2011, a large majority of the total area on which mortality was recorded.

Table 2.1—Mortality agents and complexes affecting more than 5000 ha in the conterminous United States in 2011

Agents/complexes causing mortality, 2011	Area
	ha
Mountain pine beetle[a]	1 542 877.2
Five-needle pine decline[a]	160 423.2
Spruce beetle	153 570.3
Fir engraver	128 156.5
Subalpine fir mortality[a]	122 372.5
Western pine beetle	82 649.6
Douglas-fir beetle	64 624.5
Spruce budworm	46 147.9
Ips	40 962.0
Bark beetles	38 585.5
Sudden aspen decline[b]	18 622.1
Beech bark disease	13 745.3
Emerald ash borer	9 245.1
Western balsam bark beetle[c]	9 129.3
Hemlock decline	8 125.0
Unknown	8 011.1
Balsam woolly adelgid	6 703.0
Decline	6 142.6
Flatheaded borer	5 077.3
Other mortality agents (59)	38 733.9
Total, all agents	**2 258 275.6**

Note: All values are "footprint" areas for each agent or complex. The sum of the individual agents is not equal to the total for all agents because of overlapping damage polygons.

[a] Rollup of multiple agent codes from the Insect and Disease Survey database.

[b] Includes mortality, defoliation, and decline.

[c] Also included in the subalpine fir mortality rollup.

Table 2.2—Beetle taxa included in the "western bark beetle" group

Western bark beetle taxa	Genus and species
Douglas-fir beetle	*Dendroctonus pseudotsugae*
Fir engraver	*Scolytus ventralis*
Flatheaded borer	*Buprestidae*
Ips engraver beetles	*Ips* spp.
Jeffrey pine beetle	*D. jeffreyi*
Mountain pine beetle	*D. ponderosae*
Northern spruce engraver beetle	*Ips perturbatus*
Roundheaded pine beetle	*D. adjunctus*
Silver fir beetle	*Pseudohylesinus sericeus*
Spruce beetle	*D. rufipennis*
Tip beetles	*Pityogenes* spp.
Western balsam bark beetle	*Dryocoetes confusus*
Western cedar bark beetle	*Phloeosinus punctatus*
Western pine beetle	*Dendroctonus brevicomis*
Bark beetles	Nonspecific

In addition, the survey identified 68 defoliation agents affecting about 2.84 million ha across the conterminous United States in 2011, an area slightly smaller than the land area of New Hampshire and Delaware combined. (Of these defoliation-cause categories, 4 were "rollups" of multiple agents.) The most widespread defoliators were western and eastern spruce budworms (*Choristoneura occidentalis* and *C. fumiferana*), affecting 1.95 million ha (table 2.3). Tent caterpillars (*Malacosoma* spp.), pinyon needle scale (*Matsucoccus acalyptus*), and pine butterfly (*Neophasia menapia*) each affected more than 100 000 ha.

The Forest Health Monitoring (FHM) Program Interior West region (as defined by the FHM

Table 2.3—Defoliation agents and complexes affecting more than 5000 ha in the conterminous United States in 2011

Agents/complexes causing defoliation, 2011	Area
	ha
Spruce budworm (eastern and western)[a]	1 954 235.3
Tent caterpillars[a]	284 609.0
Pinyon needle scale	260 652.0
Pine butterfly	101 339.6
Douglas-fir tussock moth	47 875.0
Winter moth	36 791.0
Aspen defoliation[b]	36 043.9
Needlecast	35 602.0
Baldcypress leafroller	17 694.3
Unknown	12 676.1
Larch casebearer	12 404.2
Larch needle blight	10 522.3
Birch leaf fungus	10 106.4
Jack pine budworm	8 507.2
Large aspen tortrix	8 411.0
Larger elm leaf beetle	7 619.3
Western hemlock looper	7 570.6
Unknown defoliator	6 737.5
Oak worms	6 266.7
Larch needle cast	5 552.0
Pinyon sawfly	5 358.6
Other defoliation agents (46)	48 592.1
Total, all agents	**2 837 254.8**

Note: All values are "footprint" areas for each agent or complex. The sum of the individual agents is not equal to the total for all agents because of overlapping damage polygons.
[a] Rollup of multiple agent codes from the Insect and Disease Survey database.
[b] Includes mortality, defoliation, and decline.

Program) had, by far, the largest area on which mortality-causing agents were detected in 2011, approximately 1.72 million ha (table 2.4). A large majority of mortality within that area was associated with mountain pine beetle, although spruce beetle, subalpine fir mortality, and five-needle pine decline were also important mortality agents and complexes.

The Getis-Ord analysis detected the three largest and most clustered hot spots of mortality exposure in the Interior West region (fig. 2.2). The most intense was centered on the M331I-Northern Parks and Ranges ecoregion section of north-central Colorado and south-central Wyoming and included much of M331H-North Central Highlands and Rocky Mountains and M331G-Southern Central Highlands. This hot spot, not surprisingly, was associated with extensive mountain pine beetle mortality in lodgepole and ponderosa pine forests. Spruce beetle mortality was also present. Meanwhile, a very large hot spot of mortality exposure, also caused primarily by mountain pine beetle, extended across several ecoregions in central Idaho and western Montana, including M332E-Beaverhead Mountains, M322B-Northern Rockies and Bitterroot Valley, M332D-Belt Mountains, M332A-Idaho Batholith, M332F-Challis Volcanics, and M331A-Yellowstone Highlands. This hot spot overlapped with a third hot spot centered on M331J-Wind River Mountains of Wyoming and that extended into the neighboring M331D-Overthrust Mountains and the Yellowstone Highlands. In addition to mountain pine beetle, five-needle pine decline was a major cause of mortality in this area.

Table 2.4—The top five mortality agents or complexes for each Forest Health Monitoring region in 2011

Mortality agents, 2011	Area
	ha
Interior West	
Mountain pine beetle[a]	1 339 848.3
Spruce beetle	147 567.0
Subalpine fir mortality[a]	118 752.1
Five-needle pine decline[a]	130 800.2
Douglas-fir beetle	51 964.5
Other mortality agents (18)	101 196.4
Total, all agents	**1 715 790.3**
North Central	
Spruce budworm	46 147.9
Mountain pine beetle[a]	26 911.1
Beech bark disease	13 253.1
Emerald ash borer	5 708.9
Oak wilt	1 053.2
Other mortality agents (13)	1 193.9
Total, all agents	**94 268.1**
North East	
Unknown	6 354.7
Forest tent caterpillar	4 667.2
Decline	4 600.5
Gypsy moth	3 791.2
Emerald ash borer	3 536.2
Other mortality agents (33)	7 344.2
Total, all agents	**30 013.8**

Mortality agents, 2011	Area
	ha
South	
Hemlock woolly adelgid	1 433.5
Southern pine beetle	88.4
Unknown	43.8
Ips	39.9
Bark beetles (nonspecific)	39.6
Black turpentine beetle	0.1
Total, all agents	**1 645.2**
West Coast	
Mountain pine beetle[a]	176 117.2
Fir engraver	121 722.6
Western pine beetle	59 443.6
Bark beetles (nonspecific)	38 399.5
Douglas-fir beetle	12 660.0
Other mortality agents (26)	45 985.1
Total, all agents	**416 558.2**
Alaska	
Spruce beetle	19 761.2
Alaska yellow-cedar decline	10 833.9
Northern spruce engraver beetle	2 675.5
Unspecified mortality	2 519.8
Western balsam bark beetle	1.0
Total, all agents	**35 791.5**

Note: The total area affected by other agents is listed at the end of each section. All values are "footprint" areas for each agent or complex. The sum of the individual agents may not equal the total for all agents because of overlapping damage polygons.

[a] Rollup of multiple agent codes in the Insect and Disease Survey database.

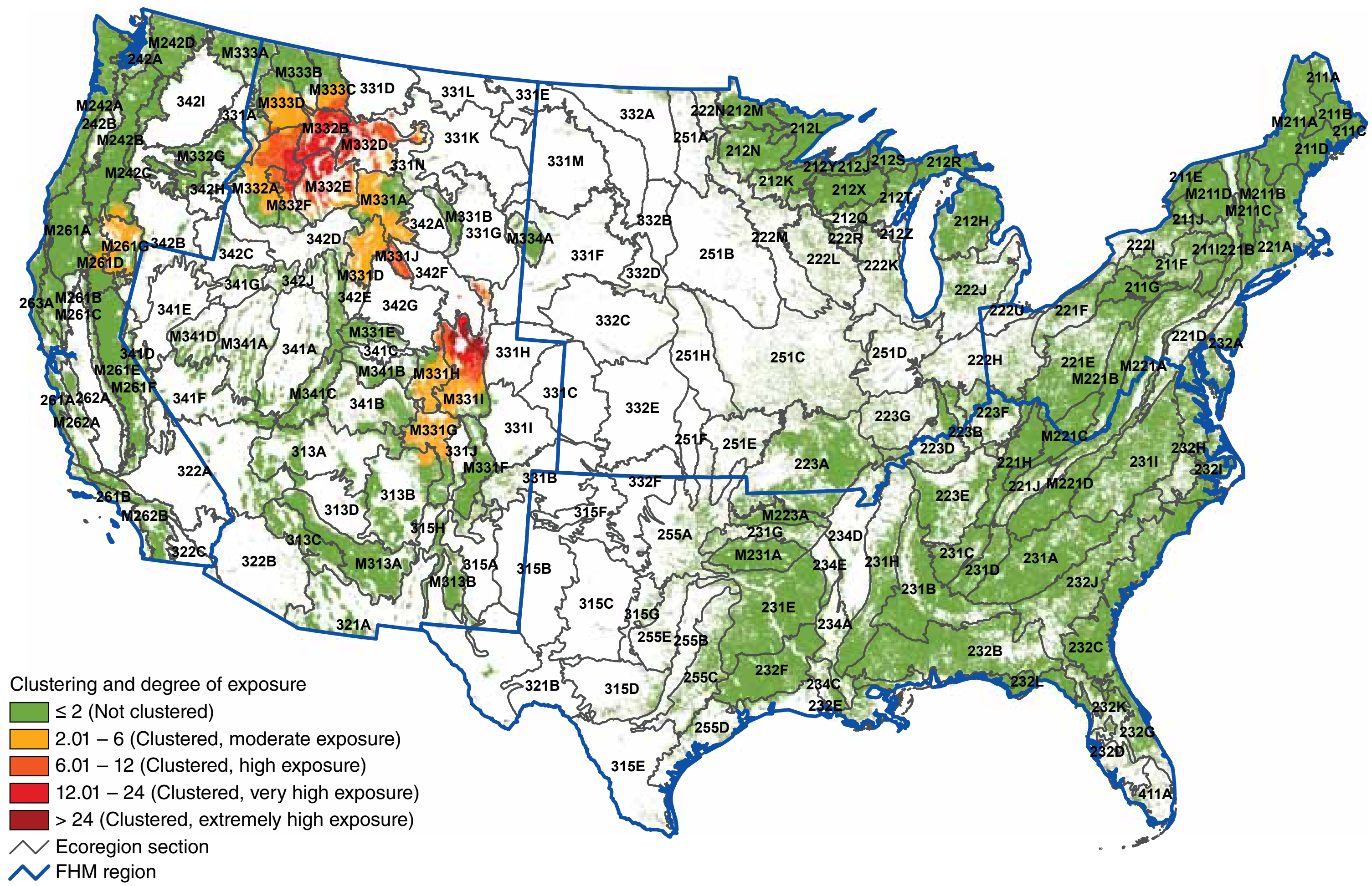

Figure 2.2—Hot spots of exposure to mortality-causing insects and diseases in 2011. Values are Getis-Ord G_i^* scores, with values > 2 representing significant clustering of high percentages of forest area exposed to mortality agents. (No areas of significant clustering of low percentages of exposure, <-2, were detected.) The gray lines delineate ecoregion sections (Cleland and others 2007); the blue lines delineate Forest Health Monitoring regions. Background forest cover is derived from MODIS imagery by the USDA Forest Service Remote Sensing Applications Center. (Data source: USDA Forest Service, Forest Health Protection Program.)

Mountain pine beetle was also a leading cause of mortality in the West Coast region, where mortality-causing agents and complexes were recorded on nearly 417 000 ha (table 2.4). Several other types of bark beetles, including fir engraver and western pine beetle (*D. brevicomis*), were also important causes of mortality in this region. These bark beetles, especially mountain pine beetle and fir engraver, were associated with a relatively low-intensity geographic hot spot of mortality in northeastern California and south-central Oregon (fig. 2.2). This hot spot encompassed M242C-Eastern Cascades, M261D-Southern Cascades, and M261G-Modoc Plateau.

Mountain pine beetle was the second most widely detected mortality agent in the North Central region, behind spruce budworm. Beech bark disease (*Nectria coccinea*) and emerald ash borer (*Agrilus planipennis*) were also important mortality agents. Mortality-causing agents and complexes were detected on approximately 94 000 ha in the region (table 2.4).

As in the North Central region, no mortality hot spots occurred in the North East and South FHM regions. In the North East, however, mortality was recorded on 30 000 ha, with forest tent caterpillar (*Malacosoma disstria*) the most widely named causal agent. In the South, mortality was detected on 1600 ha, with hemlock woolly adelgid (*Adelges tsugae*) the most commonly reported agent (table 2.4). In addition, record-setting drought in Texas, much of Louisiana, and other areas in the South, often associated with pests such as pine engraver beetles, contributed to widespread, often scattered mortality of pines and hardwoods, which occurred in late summer and early fall (Alabama Forestry Commission 2012, Louisiana Department of Agriculture and Forestry 2012, Texas Forest Service 2012) and was largely undocumented by routine detection surveys.

As with mortality, the Interior West FHM region encompassed the greatest area on which defoliating agents and complexes were detected in 2011, about 1.9 million ha (table 2.5). Western spruce budworm was the most widely detected defoliator in the region, but pinyon needle scale was also important. A large complex of geographic hot spots of defoliation, contained mostly in Idaho and Montana, was associated with western spruce budworm in the Interior West in 2011 (fig. 2.3). This complex of hot spots included:

- A large and intense hot spot centered on M333D-Bitterroot Mountains and extending into M333A-Okanogan Highland, M333B-Flathead Valley, and M333C-Northern Rockies.
- Another large and intense hot spot centered on M332A-Idaho Batholith and M332F-Challis Volcanics and extended into M332E-Beaverhead Mountains.
- A large hot spot taking in M332D-Belt Mountains and extending into M332B-Northern Rockies and Bitterroot Valley, M333C-Northern Rockies, and M331A-Yellowstone Highlands.

Table 2.5—The top five defoliation agents or complexes for each Forest Health Monitoring region in 2011

Defoliation agents, 2011	Area
	ha
Interior West	
Western spruce budworm	1 515 696.6
Pinyon needle scale	258 016.0
Douglas-fir tussock moth	43 655.9
Aspen defoliation[a]	32 745.7
Needlecast	32 565.8
Other defoliation agents (24)	51 870.3
Total, all agents	**1 906 426.2**
North Central	
Spruce budworm	116 499.7
Forest tent caterpillar	32 207.7
Jack pine budworm	8 507.2
Large aspen tortrix	7 771.8
Larch casebearer	4 627.2
Other defoliation agents (12)	15 711.7
Total, all agents	**183 226.1**
North East	
Winter moth	36 791.0
Birch leaf fungus	10 106.4
Forest tent caterpillar	6 913.3
Loopers	4 444.6
Unknown	2 469.9
Other defoliation agents (19)	9 021.2
Total, all agents	**68 791.6**
South	
Forest tent caterpillar	238 265.5
Baldcypress leafroller	17 694.3
Larger elm leaf beetle	7 619.3
Oak worms	6 266.7
Unknown	4 265.2
Other defoliation agent (1)	4.9
Total, all agents	**256 519.7**
West Coast	
Western spruce budworm	321 545.6
Pine butterfly	101 022.2
Larch casebearer	7 777.0
Ponderosa pine sawfly	4 640.2
Douglas-fir tussock moth	4 219.1
Other defoliation agents (16)	16 406.5
Total, all agents	**422 291.1**
Alaska	
Defoliators (nonspecific)	81 412.3
Aspen leaf miner	56 312.3
Willow leafblotch miner	25 829.4
Hemlock sawfly	4 514.0
Spruce aphid	1 665.7
Other defoliation agents (5)	2 977.4
Total, all agents	**166 660.8**

Note: The total area affected by other agents is listed at the end of each section. All values are "footprint" areas for each agent or complex. The sum of the individual agents may not equal the total for all agents because of overlapping damage polygons.

[a] Includes mortality, defoliation, and decline.

An additional defoliation hot spot associated mostly with western spruce budworm, along with some aspen defoliation, occurred in northern New Mexico and southern Colorado, mostly in M331G-South Central Highlands, M331F-Southern Parks and Rocky Mountain Range, 313B-Navajo Canyonlands, and 331J-Northern Rio Grande Basin (fig. 2.3). Finally, a hot spot in Nevada was caused by pinyon needle scale extending across forested parts of M341D-West Great Basin and Mountains, 341F-Southeastern Great Basin, M341A-East Great Basin and Mountains, and 341D-Mono.

Western spruce budworm was also the most important defoliator in the West Coast region, accounting for the majority of the 422 000 ha of defoliation detected there. Pine butterfly was the second leading defoliation agent; no other agent or complex was nearly as widespread as these two (table 2.5). The more intense of the two defoliation hot spots in the region was caused by infestations of western spruce budworm and pine butterfly in M332G-Blue Mountains and 342H-Blue Mountains Foothills of Oregon (fig. 2.3). Western spruce budworm was the cause of a second hot spot in M333A-Okanogan Highland and M242D-Northern Cascades of northern Washington.

Spruce budworm was similarly the leading defoliator detected in the North Central region, recorded on about 117 000 ha of the 183 000 ha of defoliation. It was followed in extent by forest tent caterpillar (table 2.5). Jack pine budworm (*C. pinus*) and spruce budworm

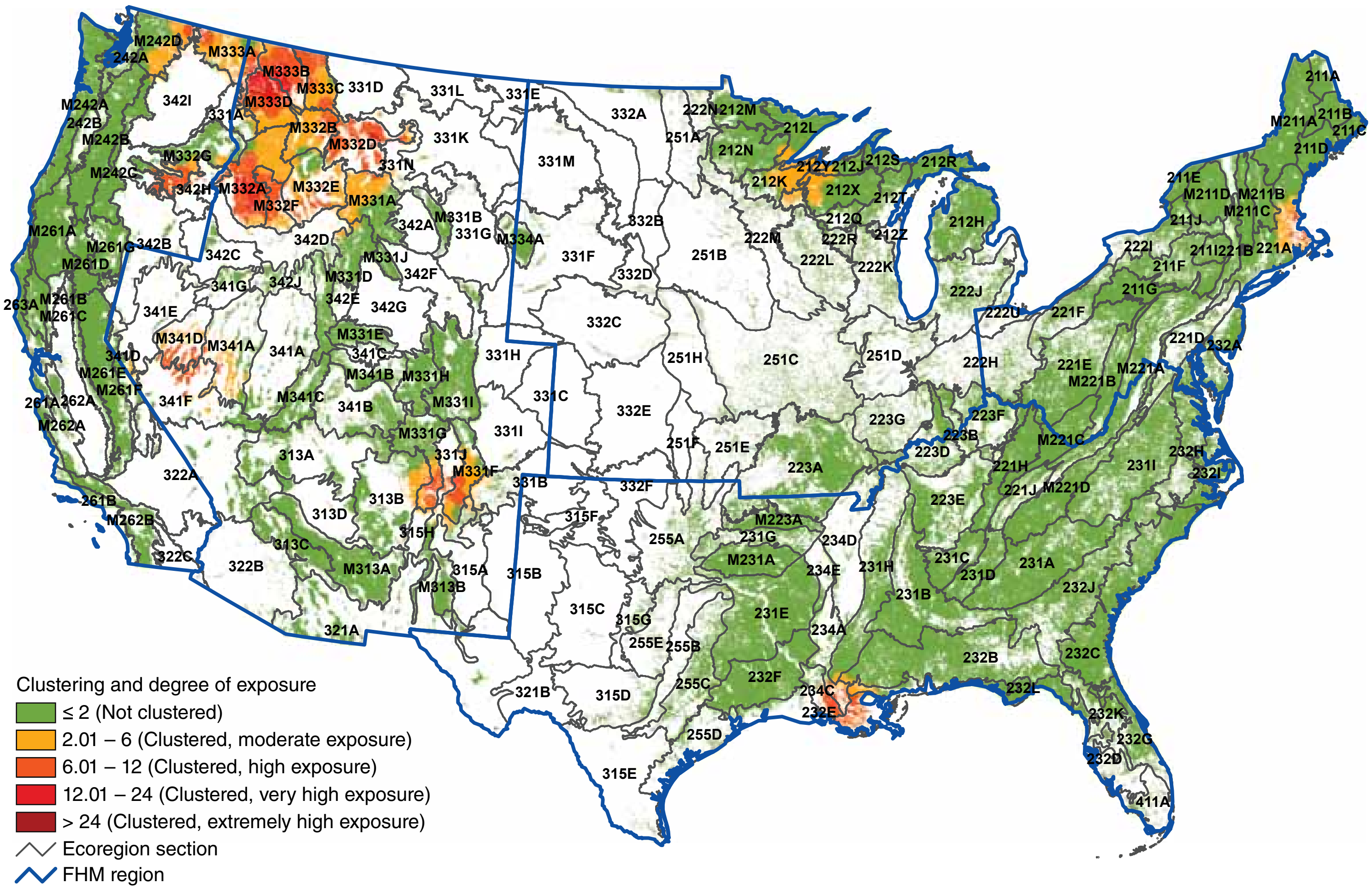

Figure 2.3—Hot spots of exposure to defoliation-causing insects and diseases in 2011. Values are Getis-Ord G_i^* scores, with values > 2 representing significant clustering of high percentages of forest area exposed to defoliation agents. (No areas of significant clustering of low percentages of exposure, <-2, were detected.) The gray lines delineate ecoregion sections (Cleland and others 2007); the blue lines delineate Forest Health Monitoring regions. Background forest cover is derived from MODIS imagery by the USDA Forest Service Remote Sensing Applications Center. (Data source: USDA Forest Service, Forest Health Protection Program.)

were the assigned causal agents associated with the region's defoliation hot spot in 212K-Western Superior Uplands, 212L-Northern Superior Uplands, 212Q-North Central Wisconsin Uplands, 212X-Northern Highlands, 212Y-Southwest Lake Superior Clay Plain, and 212J-Southern Superior Uplands (fig. 2.3).

The single defoliation hot spot in the North East FHM region, meanwhile, was caused by winter moth (*Operophtera brumata*) in 221A-Lower New England; winter moth was the most commonly detected defoliation agent in the region, found on 37 000 ha of 69 000 ha on which defoliation was recorded (table 2.5). Birch leaf fungus (*Septoria betulae*) was the second most widely detected defoliator.

Forest tent caterpillar was by far the leading defoliating agent in the South region, detected on 238 000 ha of the 257 000 ha on which defoliation was detected (table 2.5). An intense hot spot was caused by forest tent caterpillar and baldcypress leafroller (*Archips goyerana*) in southern Louisiana, in 234C-Atchafalaya and Red River Alluvial Plains, 234A-Southern Mississippi Alluvial Plain, and 232E-Louisiana Coastal Prairie and Marshes.

In 2011, five mortality-causing agents and complexes were reported for Alaska, affecting approximately 36 000 ha (table 2.4). Alaska contains about 51.3 million ha (126.9 million acres) of forest (Smith and others 2009).

Spruce beetle was the most widely detected mortality agent, affecting about 20 000 ha of forest, mostly in the south-central part of the State. Yellow-cedar (*Chamaecyparis nootkatensis*) decline was the second most widely detected mortality agent, found on about 11 000 ha in the Alaska panhandle. Northern spruce engraver beetle (*Ips perturbatus*) was detected on about 3000 ha of forest, mostly in the central and east-central parts of the State. The ecoregions with the highest percentage of surveyed forest affected by mortality agents (fig. 2.4) were M129A-Seward Mountains of east-central Alaska (1.61 percent), and M213A-Northern Aleutian Range and 213B-Cook Inlet Lowlands of south-central Alaska (1.50 and 1.00 percent, respectively).

The study detected 10 defoliation agents and complexes on nearly 167 000 ha (table 2.5) in Alaska during 2011. For nearly half of that area, approximately 81 000 ha, nonspecific defoliators were the assigned cause of defoliation. Aspen leaf miner (*Phyllocnistis populiella*) was detected on 56 000 ha, mostly in the eastern and central parts of Alaska. The next most important defoliator in 2011 was willow leafblotch miner (*Micrurapteryx salicifoliella*), found on nearly 26 000 ha. Hemlock sawfly (*Neodiprion tsugae*) was observed on about 4500 ha, and spruce aphid (*Elatobium abietinum*) was found on less than 2000 ha.

The Alaska ecoregion with the highest proportion of surveyed forest affected by defoliation was M212B-Kenai Mountains in the south-central part of the State, with 4.48 percent (fig. 2.5). Other ecoregions with relatively high levels of defoliation detection were in east-central Alaska, including 139A-Yukon Flats

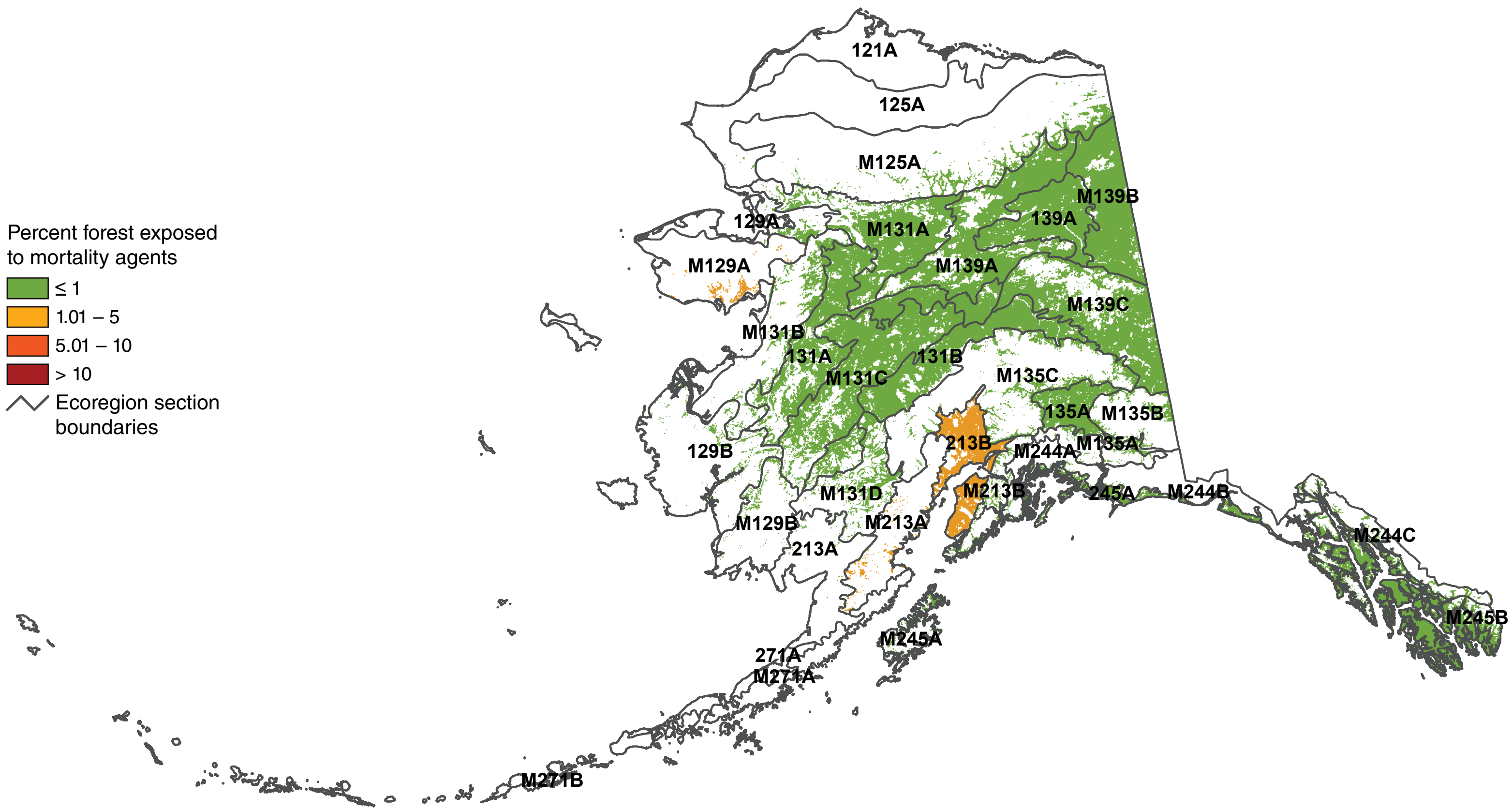

Figure 2.4—Percent of surveyed forest in Alaska ecoregion sections exposed to mortality-causing insects and diseases in 2011. The gray lines delineate ecoregion sections (Nowacki and Brock 1995). Background forest cover is derived from MODIS imagery by the USDA Forest Service Remote Sensing Applications Center. (Data source: USDA Forest Service, Forest Health Protection Program.)

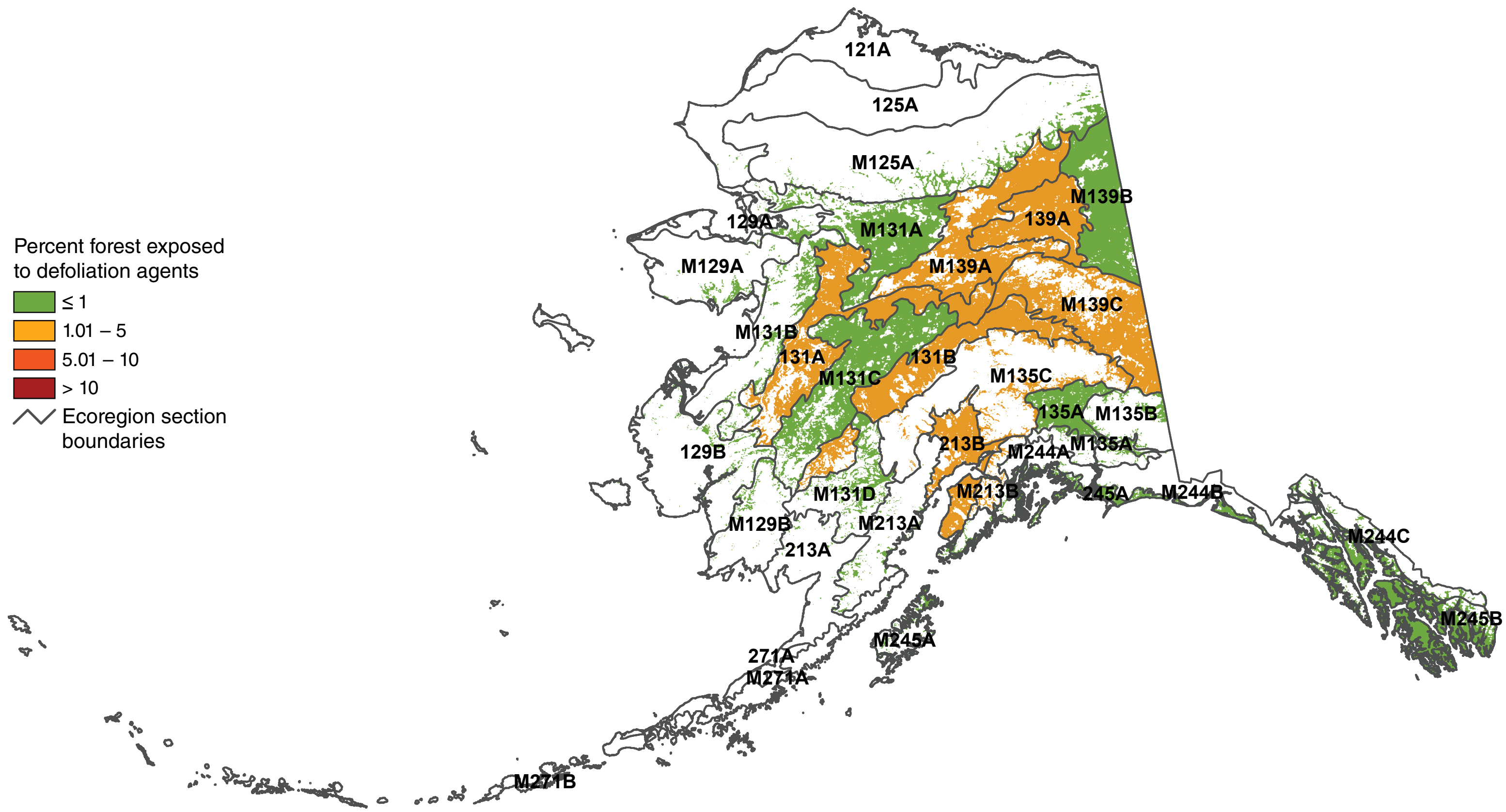

Figure 2.5—Percent of surveyed forest in Alaska ecoregion sections exposed to defoliation-causing insects and diseases in 2011. The gray lines delineate ecoregion sections (Nowacki and Brock 1995). Background forest cover is derived from MODIS imagery by the USDA Forest Service Remote Sensing Applications Center. (Data source: USDA Forest Service, Forest Health Protection Program.)

section, with 3.37 percent; M139C-Dawson Range, with 3.24 percent; and M135C-Alaska Range, with 2.28 percent.

Continued monitoring of insect and disease outbreaks across the United States will be necessary for determining appropriate followup investigation and management activities. Because of the limitations of survey efforts to detect certain important forest insects and diseases, the pests and pathogens discussed in this chapter do not include all the biotic forest health threats that should be considered when making management decisions and budget allocations. As these analyses demonstrate, however, large-scale assessments of mortality and defoliation exposure, including geographical hot spot detection analyses, offer a potentially useful approach for prioritizing geographic areas where the concentration of monitoring and management activities would be most effective.

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