CHAPTER 6.

Fragmentation of Eastern United States Forest Types

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INTRODUCTION

Fragmentation is a continuing threat to the sustainability of forests in the Eastern United States, where land use changes supporting a growing human population are the primary driver of forest fragmentation (Stein and others 2009). While once mostly forested, approximately 40 percent of the original forest area has been converted to other land uses, and most of the remainder is not original forest (Smith and others 2009). The direct loss of forest land is an obvious threat; less obvious are the threats posed by isolation and edge which encompass a wide range of negative biotic and abiotic influences on remnant forest (e.g., Forman and Alexander 1998, Harper and others 2005, Laurance 2008, Murcia 1995, Ries and others 2004). Landcover data from 1992 indicated that forest tended to be dominant and well-connected where it occurred, but also that fragmentation was so pervasive that only 10 percent of the eastern forest area was not fragmented at a landscape scale of 66 ha, and that at least 40 percent of forest area was within 90 m of forest edge (Riitters and others 2002, 2004). Between 1992 and 2001, there was a net loss of interior forest in the east, and landscapes once dominated by forest are now dominated by other land uses (Wickham and others 2007, 2008). In 16 of the 31 Eastern States, the wildland-urban interface now encompasses more than 25 percent of total land area (Radeloff and others 2005), and one-third of the eastern forest exists within neighborhoods that also contain at least 10 percent agricultural landcover (Riitters 2011).

The objective of this section is to demonstrate an approach to improve national assessments of forest fragmentation by incorporating information about the specific forest types that are fragmented. National assessments are appropriately based on high resolution, wall-to-wall landcover maps (Heinz Center 2008), but the current generation of those maps does not describe in much detail the forest types that are fragmented. Such information could improve land management and policy by identifying forest types of special concern for conservation or remediation, especially if fragmentation is related to specific ecological services like wildlife habitat or water quality (e.g., Burkhard and others 2009; Kienast and others 2009). The approach demonstrated here combines landcover data from the 2001 National Land Cover Data (NLCD) landcover map (Homer and others 2007) with field plot information from the Forest Inventory and Analysis (FIA) Program of the Forest Service, U.S. Department of Agriculture (USDA Forest Service 2010). We evaluate the fragmentation status of forest types in the Eastern United States (fig. 6.1) and estimate the area of intact forest by forest type.

Figure 6.1—The study area includes 31 Eastern States.

METHODS

Bechtold and Patterson (2005) provide a detailed description of the FIA inventory which may be summarized as follows. The FIA inventory uses a permanent, national, grid-based, equal probability sample design across all land. Each sample location is determined to be either a forest land use or a non-forest land use. For those locations determined to be a forest land use, a field inventory plot is installed to collect additional information. A variety of site and vegetation measurements are taken on a cluster of four fixed-area subplots spanning approximately 0.4 ha, which may extend into more than one forest type. FIA uses a post-stratified estimator, which accounts for different sampling intensities that arise because of intentional increases in sample size or unintentionally as a result of survey nonresponse. In effect, each plot has a weight factor that accounts for those differences. In addition, each within-plot forest type is weighted by its relative area on the field plot. The area estimates that we report were derived by combining the two weight factors (Bechtold and Patterson 2005). We used data from 152,804 plot locations across the study area, using the most recent measurement for measurement years 2000 to 2008. Forest types were defined by FIA protocols (USDA Forest Service 2010). We selected 75 of the 92 forest types in the FIA database by excluding nonstocked forest land and the forest types which occupied less than 70 000 ha each.

Fragmentation was measured using the 2001 NLCD landcover map (Homer and others 2007). The NLCD map identifies 16 landcover types at a spatial resolution of 0.09 ha per pixel and a minimum mapping unit of 0.45 ha. The 16 NLCD landcover types were combined into two generalized landcover types called forest (including the NLCD deciduous forest, evergreen forest, mixed forest, and woody wetlands classes) and non-forest (including all other NLCD classes). Forest area density (Pf), defined as the proportion of a fixed-area neighborhood that has forest landcover, was measured within a 4.41 ha (7 pixel X 7 pixel) neighborhood centered on each inventory plot location (Riitters and others 2002). That neighborhood size was large enough to reliably estimate Pf yet small enough to characterize fragmentation in the immediate vicinity of a field plot. Pf was converted to a categorical variable (Pf class) with seven classes labeled as intact ($Pf = 1.0$), interior ($0.9 \le Pf < 1.0$), dominant ($0.6 \le Pf < 0.9$), transitional ($0.4 \le Pf < 0.6$), patchy ($0.1 \le Pf < 0.4$), rare ($0.0 < Pf < 0.1$), and none ($Pf = 0.0$). The class "none" was included because it was possible for inventory plots to occur in neighborhoods containing no forest landcover. The Pf class was then treated as a new plot-level attribute when using the FIA weight factors to summarize Pf classes by forest types.

RESULTS

The percentage of each forest type's total area that is in each of the seven Pf classes is shown in figure 6.2. The forest types are sorted in

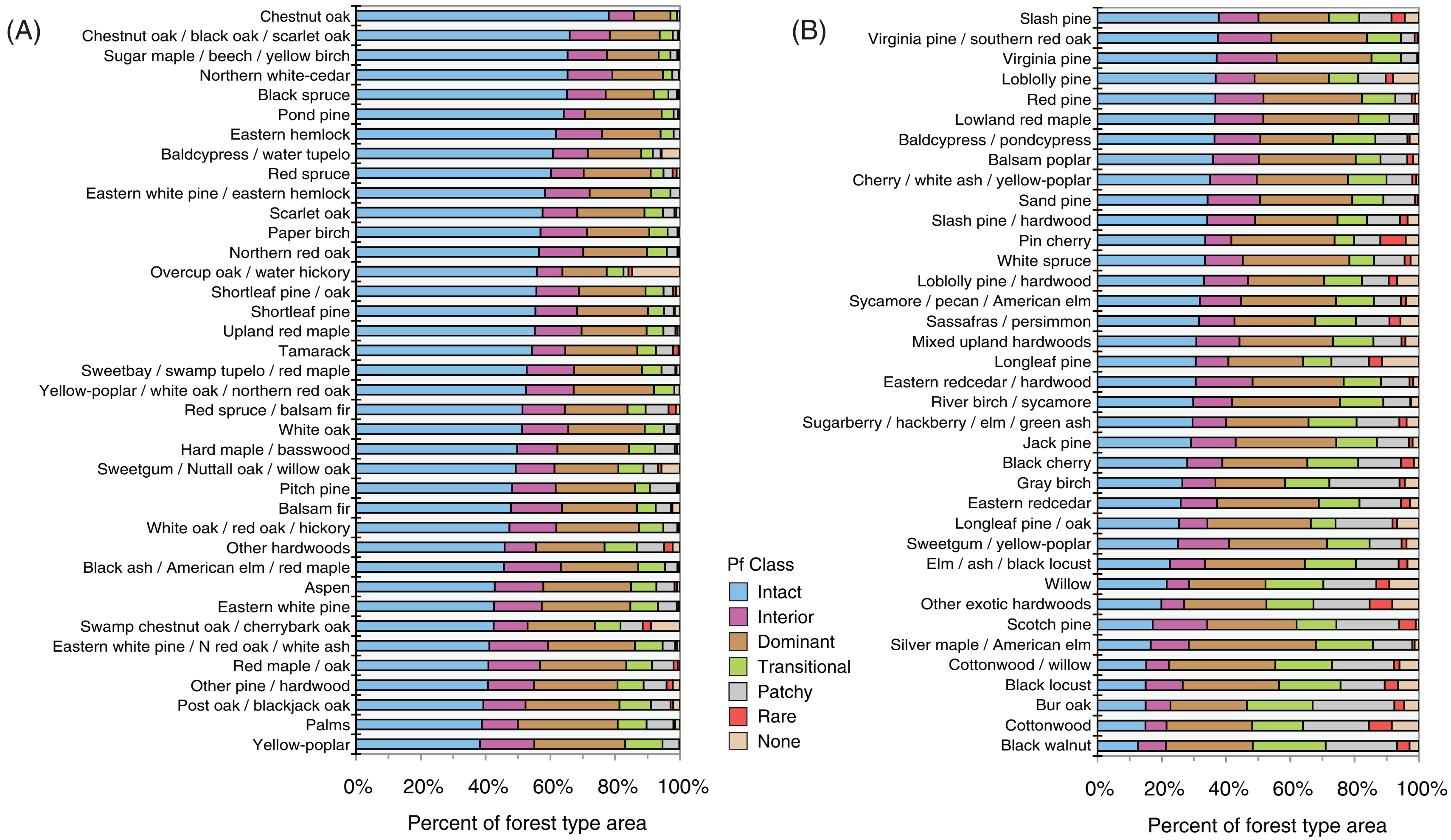

Figure 6.2—The percentage of total forest type area in each of seven forest area density (Pf) classes, sorted descending by percentage in the intact area density class. Forest type nomenclature is from appendix F of USDA Forest Service (2010).

descending order by percentage of intact forest landcover, such that the forest type with the highest percentage (chestnut oak) is at the top of figure 6.2A and that with the lowest percentage (black walnut) is at the bottom of figure 6.2B. In figure 6.3, the estimated area of intact forest landcover is shown for each forest type sorted in descending order. Note the scale change on the x-axis between figure 6.3A and figure 6.3B.

DISCUSSION

Over all forest types, approximately 81 percent of forest area was contained in a neighborhood that consisted of at least 60 percent forest landcover (Pf classes dominant, interior, and intact), and approximately 45 percent was contained in a neighborhood with intact forest landcover. While these results apply to forest land area as defined by the FIA inventory, they are generally consistent with earlier estimates of dominant and intact eastern forest that were made for forest landcover in general (Riitters and others 2002, Wickham and others 2008). The high percentage (81 percent) of area with sufficient forest landcover to qualify as dominant indicates that forest landcover tends to be dominant where forest occurs, and the low percentage (45 percent) of intact forest indicates that fragmentation is pervasive.

The percentage area in the intact forest area density class varied from 13 percent to 78 percent among individual forest types. Fragmentation would be considered a natural attribute of many of the forest types that exhibited low percentages of intact forest. For example, cottonwood and willow are typical of narrow riparian forests in the semi-arid western part of the study area, and intactness is lost from fragmentation by water. Bur oak is an example of naturally fragmented forest in savannah regions where fragmentation by grass-shrub landcover is a natural condition. Forest types exhibiting the largest percentages of intact forest are partly explained by (lack of) accessibility due to steep slopes, e.g., chestnut oak, or hydric soils, e.g., northern white cedar, black spruce, pond pine. Perhaps the best evidence for the pervasiveness of fragmentation is between those extremes, for the forest types that are not naturally fragmented and that occur in relatively accessible locations; typically less than half of the area of those forest types qualified as intact forest in a modest 4.41 ha neighborhood. Except for "natural" fragmentation by water or grassland, the majority of that fragmentation is associated with anthropogenic land uses such as agriculture, housing, and infrastructure (Riitters and Coulston 2005, Wade and others 2003).

The regional supply of intact forest is driven more by total area than by the characteristics of individual forest types. A large share of the total area of intact forest was contributed by the sugar maple/beech/yellow birch forest type (fig. 6.2A), which exhibited the second-largest percentage of intact forest on a per-forest type basis and which occupied a large share of total forest area. In contrast, large shares of total intact forest area were also contributed by three forest types (mixed upland hardwoods, loblolly pine, white oak/red oak/hickory) that individually

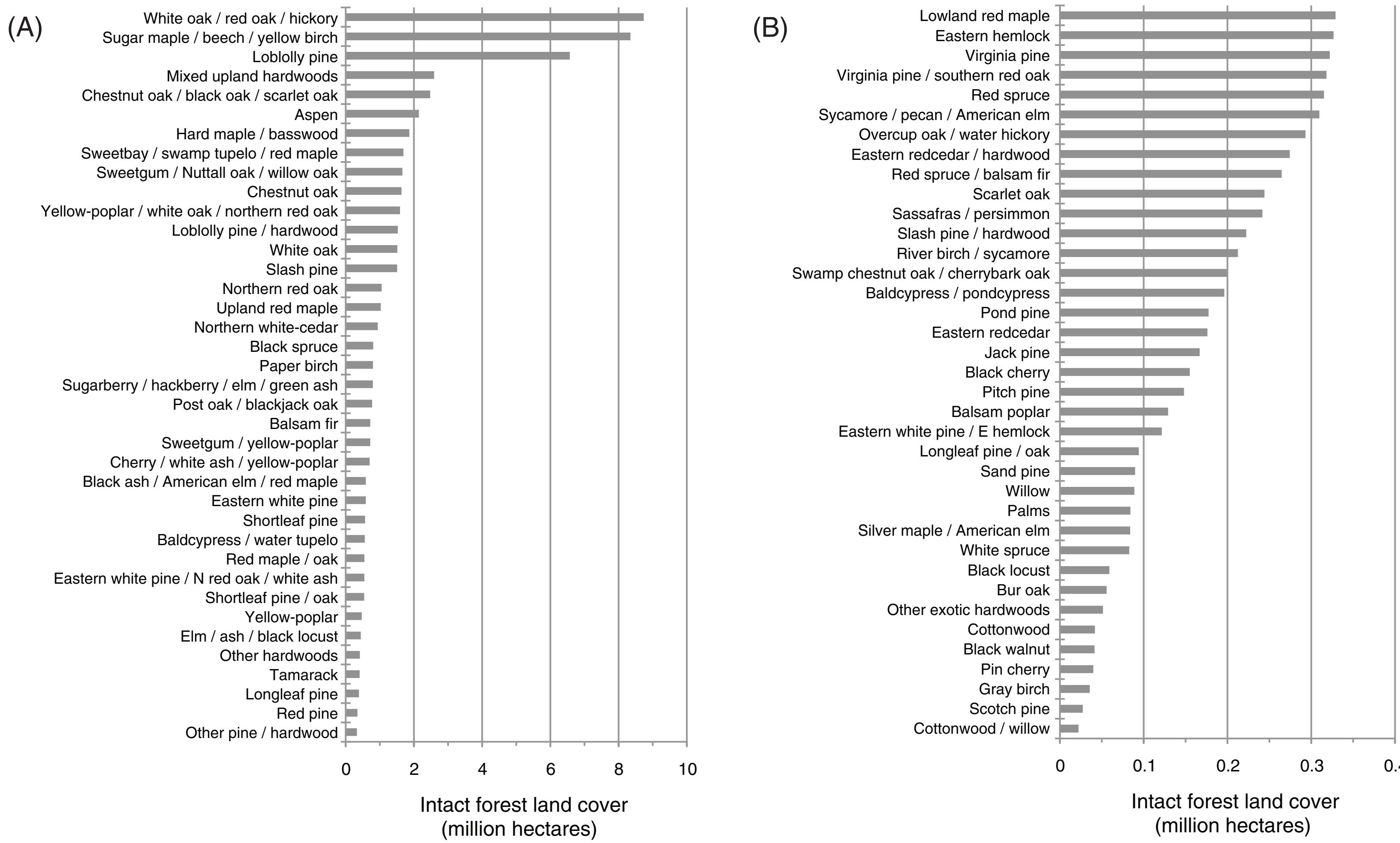

Figure 6.3—Estimated total area of intact forest landcover, by forest type, sorted descending by area. Note the scale change between (A) and (B). Forest type nomenclature is from appendix F of USDA Forest Service (2010).

exhibited moderate to low percentages of intact forest but that occupied a large share of total forest area. Approximately 36 percent of intact forest area was concentrated in only three forest types—white oak/red oak/hickory, sugar maple/beech/yellow birch, and loblolly pine—and the 37 forest types with the least individual intact areas together comprised only 9 percent of total intact forest area. Mitigation of fragmentation and conservation of intact forest may be desired to improve the sustainability of ecological services obtained from specific forest types. If so, land management plans should be specifically directed at those types because plans aimed generally at conserving intact forest would be directed disproportionally to the most common forest types.

In summary, previous national assessments of forest fragmentation did not account for potential differences among forest types because the landcover maps which portray fragmentation did not identify forest types (USDA Forest Service 2001, 2004). This section demonstrated an approach to estimating the degree and area of fragmentation by forest type by combining landcover maps with field inventory data. The statistical features of the field inventory system permit forest types to be compared in terms of the fragmentation that they experience, and permit estimation of fragmented landcover area in a way that is consistent with national forest inventory. In principle, fragmentation data may be summarized by other plot attributes such as ownership by using the methods demonstrated here.

LITERATURE CITED

Bechtold, W.A.; Patterson, P.L., eds. 2005. The enhanced forest inventory and analysis program–national sampling design and estimation procedures. Gen. Tech. Rep. SRS-80. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 85 p.

Burkhard, B.; Kroll, F.; Muller, F.; Windhorst, W. 2009. Landscapes' capacities to provide ecosystem services – a concept for land-cover based assessments. Landscape Online. 15: 1-22.

Forman, R.T.T.; Alexander, L.E. 1998. Roads and their major ecological effects. Annual Review of Ecology, Evolution, and Systematics. 29: 207-231.

Harper, K.A.; MacDonald, S.E.; Burton, P.J. [and others] 2005. Edge influence on forest structure and composition in fragmented landscapes. Conservation Biology. 19: 768-782.

Heinz Center. 2008. Landscape pattern indicators for the nation: a report from the Heinz Center's landscape pattern task group. Washington, DC: The H. John Heinz III Center for Science, Economics and the Environment. 108 p.

Homer, C.; Dewitz, J.; Fry, J. [and others] 2007. Completion of the 2001 national land cover database for the conterminous United States. Photogrammetric Engineering and Remote Sensing. 73: 337-341.

Kienast, F.; Bolliger, J.; Potschin, M. [and others] 2009. Assessing landscape functions with broad-scale environmental data: insights gained from a prototype development for Europe. Environmental Management. 44: 1099-1120.

Laurance, W.F. 2008. Theory meets reality: how habitat fragmentation research has transcended island biogeography theory. Biological Conservation. 141: 1731-1744

Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. Trends in Ecology and Evolution. 10: 58-62.

Radeloff, V.C.; Hammer, R.B.; Stewart, S.I. [and others] 2005. The wildland-urban interface in the United States. Ecological Applications. 15: 799-805.

Ries, L.; Fletcher, R.J.; Battin, J.; Sisk, T.D. 2004. Ecological responses to habitat edges: mechanisms, models, and variability explained. Annual Review of Ecology, Evolution and Systematics. 35: 491-522.

Riitters, K. 2011. Spatial patterns of land cover in the United States: a technical document supporting the Forest Service 2010 RPA Assessment. Gen. Tech. Rep. SRS-136. Asheville NC: U.S. Department of Agriculture Forest Service Southern Research Station. 64 p.

Riitters, K.H.; Coulston, J.W. 2005. Hotspots of perforated forest in the Eastern United States. Environmental Management. 35: 483-492.

Riitters, K.H.; Wickham, J.D.; Coulston, J.W. 2004. A preliminary assessment of Montréal process indicators of forest fragmentation for the United States. Environmental Monitoring and Assessment. 91: 257-276.

Riitters, K.H.; Wickham, J.D.; O'Neill, R.V. [and others]. 2002. Fragmentation of Continental United States forests. Ecosystems. 5: 815–822.

Smith, W.B.; Miles, P.D.; Perry, C.H.; Pugh, S.A. 2009. Forest resources of the United States, 2007. Gen. Tech. Rep. WO-78. Washington, DC: U.S. Department of Agriculture Forest Service. 336 p.

Stein, S.M.; McRoberts, R.E.; Mahal, L.G. [and others]. 2009. Private forests, public benefits: increased housing density and other pressures on private forest contributions. Gen. Tech. Rep. PNW-GTR-795. Portland, OR: U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station. 74 p.

U.S. Department of Agriculture Forest Service. 2001. 2000 RPA assessment of forest and range lands. Report FS-687. Washington, DC: U.S. Department of Agriculture Forest Service. 78 p.

U.S. Department of Agriculture Forest Service. 2004. National Report on sustainable forests 2003. Report FS-766. Washington, DC: U.S. Department of Agriculture Forest Service. 139 p.

U.S. Department of Agriculture Forest Service. 2010. The forest inventory and analysis database: database description and users manual for phase 2, version 4.0, rev. 3. Forest Inventory and Analysis Program. Washington, DC: U.S. Department of Agriculture Forest Service. 368 p. http://fia.fs.fed.us/library/database-documentation/. [Date accessed: February 18, 2011].

Wade, T.G.; Riitters, K.H.; Wickham, J.D.; Jones, K.B. 2003. Distribution and causes of global forest fragmentation. Ecology and Society. 7(2): 7. http://www.ecologyandsociety.org/vol7/iss2/art7. [Date accessed: February 17, 2011].

Wickham, J.D.; Riitters, K.H.; Wade, T.G.; Coulston, J.W. 2007. Temporal change in forest fragmentation at multiple scales. Landscape Ecology. 22: 481-489.

Wickham, J.D.; Riitters, K.H.; Wade, T.G.; Homer, C. 2008. Temporal change in fragmentation of Continental U.S. forests. Landscape Ecology. 23: 891-898.