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PATTERNS OF HOUSES AND HABITAT LOSS FROM 1937 TO 1999 IN NORTHERN WISCONSIN, USA

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Abstract. Rural America is witnessing widespread housing development, which is to the detriment of the environment. It has been suggested to cluster houses so that their disturbance zones overlap and thus cause less habitat loss than is the case for dispersed development. Clustering houses makes intuitive sense, but few empirical studies have quantified the spatial pattern of houses in real landscapes, assessed changes in their patterns over time, and quantified the resulting habitat loss. We addressed three basic questions: (1) What are the spatial patterns of houses and how do they change over time; (2) How much habitat is lost due to houses, and how is this affected by spatial pattern of houses; and (3) What type of habitat is most affected by housing development. We mapped 27 419 houses from aerial photos for five time periods in 17 townships in northern Wisconsin and calculated the terrestrial land area remaining after buffering each house using 100- and 500-m disturbance zones. The number of houses increased by 353% between 1937 and 1999. Ripley's *K* test showed that houses were significantly clustered at all time periods and at all scales. Due to the clustering, the rate at which habitat was lost (176% and 55% for 100- and 500-m buffers, respectively) was substantially lower than housing growth rates, and most land area was undisturbed (95% and 61% for 100-m and 500-m buffers, respectively). Houses were strongly clustered within 100 m of lakes. Habitat loss was lowest in wetlands but reached up to 60% in deciduous forests. Our results are encouraging in that clustered development is common in northern Wisconsin, and habitat loss is thus limited. However, the concentration of development along lakeshores causes concern, because these may be critical habitats for many species. Conservation goals can only be met if policies promote clustered development and simultaneously steer development away from sensitive ecosystems.

Key words: clustered development; disturbance zone; exurban; habitat loss; housing growth; rural sprawl.

Introduction

The United States is experiencing strong housing growth both in suburban and rural areas (Fuguitt et al. 1998, Hobbs and Stoops 2002). In the 1990s alone, 13 million new housing units were built in the United States, many of which were placed in areas with high natural amenities (McGranahan 1999). The trend toward strong housing growth in rural areas started in the late 1960s (Radeloff et al. 2005), and the 1970s was the first decade when non-metropolitan population growth rates exceeded those of metropolitan areas (Fuguitt 1985), and reoccurred in the 1990s (Beale and Fuguitt 1990, Long and Nucci 1997). Strong rural housing growth raises the question how rural sprawl is affecting the environment, and what management recommendations can be given to mitigate these effects.

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Environmental effects begin during the construction phase of a house, when natural vegetation is disturbed or removed, soil erosion is common (Brown 2003), and habitat is lost and fragmented (Theobald et al. 1997). After the construction, exotic species are introduced through gardening and landscaping (Suarez et al. 1998), and wildlife movement is restricted due to roads and fences (Friesen et al. 1995, Hostetler 1999). Accordingly, areas with higher housing density exhibit fewer neotropical migrant birds (Kluza et al. 2000, Pidgeon et al. 2007), lower densities of ground and shrub nesters (Maestas et al. 2003), higher nest abandonment (Kluza et al. 2000, Miller and Hobbs 2000), and larger populations of species that thrive in human-dominated environments, including non native species (Hoffman and Gottschang 1977, Coleman and Temple 1993). Nest predation by pets is higher near houses (Coleman and Temple 1993, Odell and Knight 2001), and avoidance behavior is common in species not adapted to human presence (Holmes et al. 1993, Rodgers and Smith 1995). The multitude of environmental effects caused by houses makes it important for conservation biologists to study and influence patterns of development (Marzluff 2002, Hansen et al. 2005, Lenth et al. 2006).

Generally speaking, clustered houses will affect a smaller portion of the land area than dispersed houses. The suggestion to cluster houses has been prominent among land use planners ever since W. H. Whyte published his classic report "Cluster development" in 1964. The motivation for cluster development is not necessarily environmental protection but often more general to protect open space, farmland, and rural character (Sullivan 1994). Ecologists have used the concept of the disturbance zone, defined as the area around a house where environmental quality is degraded (Theobald et al. 1997), to compare effects of different housing pattern, and advocate clustered development (Odell et al. 2003). At the landscape scale, the combined disturbance zones of all houses create a collective disturbance zone, which is a function of both housing density and the spatial pattern of houses. Clustering development makes intuitive sense, and empirical studies show that it can somewhat reduce environmental effects of houses (Odell and Knight 2001), although the conservation value of clustered development is not a given (Lenth et al. 2006). However, little is known about the patterns of houses in real landscapes, and how much habitat loss they caused, and even less is known about how the spatial pattern of houses has changed over time. Examining both spatial and temporal patterns jointly is important though, because environmental effects of houses may accumulate over time, and may not become apparent immediately. Theoretical models predict time lags in species extinctions (Tilman et al. 1994), and empirical evidence shows that decades may elapse before the full effects of housing development on wildlife populations and communities become evident (Doak 1995, Kirkman et al. 1996, Ligon and Stacey 2000). A better understanding of both spatial and temporal patterns of houses is thus needed to predict environmental effects of past and future development.

In addition to the spatial patterns, the question is where houses are placed in the landscape. For example, whether or not a new subdivision is clustered may matter little if it interrupts an important wildlife corridor. In a given landscape, some areas are going to be more important for biodiversity conservation than others. For example, in the Greater Yellowstone Ecosystem, housing development is largely restricted to valley bottoms, due to the topography. However, valley bottoms are also the areas where birds reproduce most successfully, making them important source areas for sink populations at higher elevation (Hansen et al. 2002). In general, people and wildlife species are often drawn to the same places (Balmford et al. 2001), and that may exacerbate the environmental effects of houses. An assessment of the environmental effects of houses thus needs to examine both spatial patterns, and the locations of houses.

The goal of our study was thus to address three basic questions: (1) what are the spatial patterns of houses in a real landscape (clustered vs. dispersed), and how did they change over time; (2) how much habitat (defined as land area outside disturbance zones) is lost due to houses, and how is this affected by spatial pattern of houses; and (3) where are houses located, i.e., what type of habitat is most affected by housing development.

Methods

Our approach consisted of three steps. First, we mapped houses from historic aerial photos of 17 townships across northern Wisconsin for five time steps from 1937 to 1999, and we quantified the spatial patterns of houses. Second, we calculated habitat loss between time steps for both 100- and 500-m disturbance zones. Third, we estimated where houses were located (1) in relation to lakeshores, and (2) in relation to major land cover types.

Study area

Our study area consisted of 17 townships (each 92 km^2 in size) in northern Wisconsin, USA (Fig. 1). Townships are the main administrative unit for which development plans are made, and they are sufficiently large to measure patterns of houses and habitat loss. To select our 17 townships, we calculated the decadal rate of change of housing density from 1940 to 1990 for each township in northern Wisconsin (Hammer et al. 2004), and used a stratified random sampling design across the range of housing density change (Fig. 1; Hawbaker et al. 2005). Sample units were stratified in three ecological subsections, areas that share relatively homogenous soils and vegetation (McNab and Avers 1994); the selected subsections represent major differences in soils, vegetation, and land use. The climate in the three subsections is characterized by cold winters and short, mild summers. The average temperature is −11°C in January and 19°C in July; annual precipitation is 71–86 mm (Martin 1965, Eichenlaub 1979).

The first ecological subsection, the Northern Highlands Pitted Outwash (Northern Highlands) is comprised of thick deposits of glacial outwash with some coarse textured moraines. Soils are sandy, and topography level to rolling. Presettlement vegetation was white and red pine forest (*Pinus resinosa, P. strobus*); now it is dominated by hardwoods, especially aspen (*Populus* spp.) and sugar maple (*Acer saccharum*). Timber production is a major land use. The Northern Highlands has one of the highest concentrations of kettle lakes in the world, and due to the inherent recreational and scenic amenities, housing growth has been extensive (Hammer et al. 2004, Radeloff et al. 2005).

The Central/Northwest Wisconsin Loess Plain (Loess Plain) is characterized by silt capped irregular plains, with sandy-loam tills over Precambrian gneiss bedrock. Presettlement vegetation was dominated by sugar maple–basswood (*Acer–Tilia*), hemlock–sugar maple

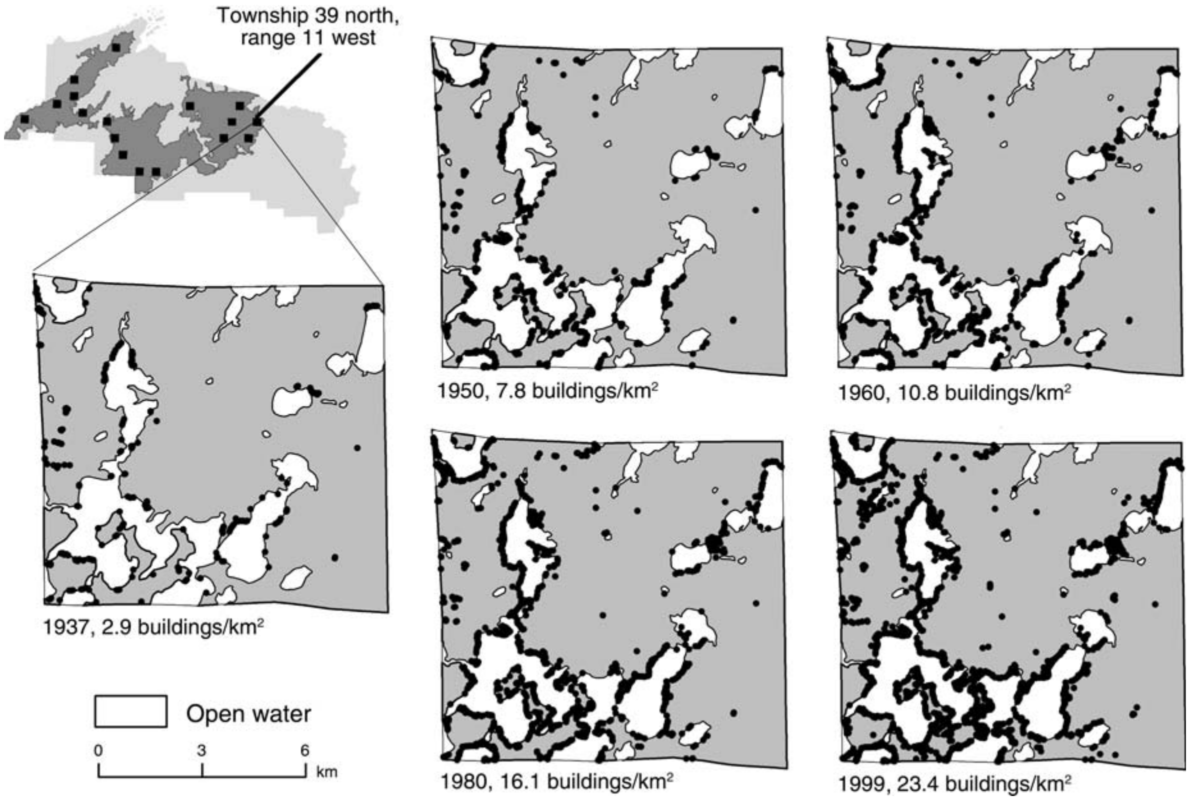

FIG. 1. Distribution of the 17 sampled townships within Wisconsin, USA, and an example of the housing patterns from 1937 to 1999 for township 39 north, range 11 west (T39N, R11W). In the study area map, the light gray area represents the counties of northern Wisconsin, the darker gray shading highlights the three ecoregions within which our samples were located, and black squares are the townships. In the township maps, white areas represent water, and gray areas represent land.

(*Tsuga–Acer*), and aspen–birch (*Populus–Betula*) forests. The current vegetation consists largely of sugar maple (*A. saccharum*), paper birch (*B. papyrifera*), and aspen (*Populus* spp.) (McNab and Avers 1994). There are abundant wetlands, but few lakes. This lack of recreational and scenic amenities limited housing and road development (Hawbaker and Radeloff 2004, Hawbaker et al. 2005).

The Bayfield Sand Plains (Bayfield Sands) are characterized by flat to steep depressional sands from the last glaciation over sandstone bedrock. The presettlement vegetation was a mixture of jack pine (*P. banksiana*), white pine (*P. resinosa*), and red pine (*P. strobus*), and pine–oak barrens (*Pinus–Quercus*) with frequent fires (Radeloff et al. 1999). Current vegetation is dominated by jack and red pine plantations; major land uses are forestry, some remnant agriculture, and dispersed recreation. Kettle lakes are scarce compared to the Northern Highlands but housing growth is common where lakes occur (Radeloff et al. 2001).

Patterns of houses over time

For each sampled township, a combination of data sources was used to map houses. The first data set was the Wisconsin Land Economic Inventory ("Bordner Survey") from the 1920s and 1930s. Its mission was to document the current and potential use of land in the state of Wisconsin, and it produced detailed maps for each township. We scanned these maps, which were available from the Wisconsin State Historical Society, and georectified them based on topographic maps.

The second data set was historic aerial photography for four time points between 1937 and 1999. In Wisconsin, the first complete coverage with large-scale photographs (1:15 000–1:20 000) dates from 1937. Since then, aerial-photo campaigns have been conducted approximately every decade. The photographs are black and white panchromatic or infrared. A total of 1133 photographs were scanned at 1-m pixel resolution and georectified onto digital orthophotos from 1992–1993 (courtesy of the Wisconsin Department of Natural Resources); average positional root mean square (RMS) error was 6.65 m. The quality of the aerial photographs from the 1930s was poor, and Bordner maps provided house locations for that period. The third source of building data was topographic maps for the 1970–1980s, available in digital raster graphic

(DRG) format (courtesy of the Wisconsin Department of Natural Resources; *available online*).[6]

The digitization of house locations was done directly on screen starting with recent decades because these aerial photographs are generally of higher quality. Housing locations present in the recent photos were then checked in prior decades, and houses that were demolished over time were added. On images taken during the summer, tree canopies can make identification of houses difficult; however, there are other features that can help in the identification of areas with a house such as lawns, driveways, docks, and garages. Distinguishing houses from other structures in a consistent manner based on aerial photographs proved infeasible, and we did not separate building types. However the vast majority of buildings in northern Wisconsin are either seasonal or permanent homes. Hence we use the term "houses" for all structures that we mapped.

Two measures were used to estimate the degree to which houses were clustered, and if so, at which scale. The first was an analysis of nearest-neighbor distances, resulting in histograms depicting the likelihood that a house will have another house within 0–100, 100–200, ..., 1700–1800 m (no longer distances were observed). The second measure of clustering was Ripley's K test (Ripley 1977). This test is a second-order statistic that uses the information on the distances between all the points and provides detailed information on the scale of the pattern, such as dispersion at broader scales, but clustering at fine scales (Ripley 1979).

Habitat loss due to houses

To calculate habitat loss due to houses, we applied buffers (100 and 500 m) around each house thus simulating their disturbance zones (Theobald et al. 1997). All our analyses of disturbance zones, and the disturbed area focused on land areas only, lake areas were not included. We selected these two buffer distances to capture a range of disturbance zones reflecting different ecological processes (e.g., noise disturbance versus nest predation by pets). We focused our analysis on habitat loss, and not habitat fragmentation, because habitat loss is more important for wildlife population viability than fragmentation, unless the proportion of habitat remaining is very low (Fahrig 1997), which was never the case in our townships. We defined habitat as all land areas outside the disturbance zones.

Each house was buffered by 100 and 500 m to estimate its disturbance zone, but clustered houses resulted in overlapping disturbance zones, and many disturbance zones included lakes. This means that a given housing growth rate does not necessarily translate to the same growth rate for the disturbed land area. We defined the disturbed land area as the total land area measured in hectares that falls within the disturbance zones of all houses. We examined this relationship in more detail, by comparing the percent change in housing density from 1937 to 1999 with the percent change of the disturbed land area in the same time period for each township. To quantify the realized terrestrial footprint of each house, we calculated the ratio of the total land area in disturbance zones in each township, divided by the number of houses, and examined how this value changed over time.

In terms of habitat types that were affected, we were particularly interested in riparian habitats along lakeshores. Houses in northern Wisconsin are often very close to lakes, due to the scenic vistas and recreational opportunities that lakes provide (Radeloff et al. 2001, Schnaiberg et al. 2002). We examined six buffers around lakes (within 50, 50–100, 100–300, 300–600, 600–1000, and >1000 m) and summed the number of houses in each buffer at each time period. We then calculated the houses-to-area ratio by dividing the percentage of houses in each buffer by the percentage of land area in the buffer. For example, if 80% of all houses in one township fall within 100 m of a lake, but this buffer contains only 20% of the total land area of that township, then the houses-to-area ratio would be four. The houses-to-area ratio is thus a measure of the clustering of houses in a given buffer. If the ratio is one, then houses are randomly distributed over the land area; if the ratio is greater than one, then houses occur more frequently than expected in that buffer.

We examined what type of habitat was lost based on the WISCLAND land cover classification (Reese et al. 2003). WISCLAND data were derived from 30-m Landsat satellite imagery from 1992–1993 and describe the distribution of coarse land cover classes. We used this information to assess (1) what proportion of each land cover class fell within the disturbance zones, and (2) if land cover composition within the disturbance zones differed from areas outside.

Results

We digitized 27 419 houses across all time periods and townships. In 1937, there were 2605 houses distributed in the sample units among the three subsections (Northern Highlands, 653; Loess Plain, 1246; and Bayfield Sands, 706); compared to 9212 in 1999 (Northern Highlands, 4275; Loess Plain, 2442; and Bayfield Sands, 2495). The number of houses increased in every time step. The Loess Plain exhibited the highest housing density in 1937, (2.7 houses/km^2) compared with 1.3 houses/km^2 in both Bayfield Sands and Northern Highlands (Fig. 2). However, growth rates differed, and by 1960, housing density in the Northern Highlands surpassed the other two subsections and reached 9 houses/km^2 by 1999 (Fig. 2).

Increasing housing density resulted in decreasing nearest-neighbor distances (Fig. 3). In 1937, only three of the 12 townships in the Bayfield Sands and the

[6] ⟨http://dnr.wi.gov/maps/gis/datadrg.html⟩

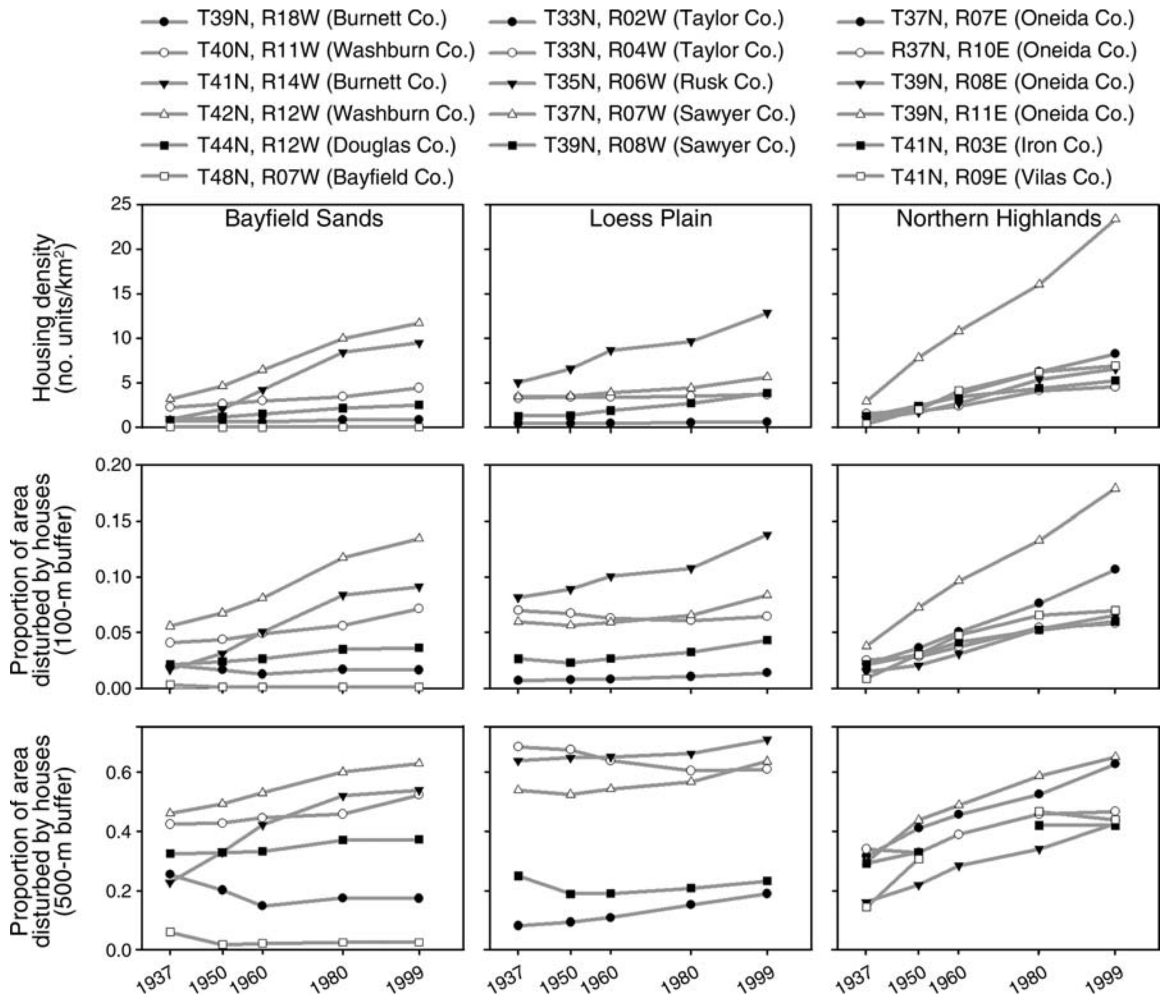

FIG. 2. Housing density (top row), the proportion of disturbed area with a 100-m disturbance zone (center row), and the proportion of disturbed area with a 500-m disturbance zone (bottom row) for each township in the three ecoregions: Bayfield Sands (left column), Loess Plain (center column), and Northern Highlands (right column). Please note the difference in *y*-axis range between the two bottom rows. Symbol types designate different counties (Co.).

Northern Highlands exhibited clustered patterns, where more than 75% of all houses had a neighboring house within 100 m. In contrast, in 1937 the Loess Plain already showed high frequencies of short nearest-neighbor distances. By 1999, however, 15 of our 17 townships exhibited clustered patterns where more than 75% of all houses had a neighboring house within 100 m. Ripley *K* tests confirmed the observed pattern of strong clustering (Fig. 4). Clustering was most pronounced at scales of 3–4 km, and in the 1950s in the example, but both scale and timing of peak clustering varied slightly among townships. However, since houses can not be built on lakes it is important to point out that some of the clustering observed in the Ripley's *K* tests may thus simply be caused by the fact that land itself is clustered.

Habitat loss

As expected, increasing housing density between 1937 and 1999 caused more disturbed land area. In 1999, 7% of the study area was disturbed assuming a 100-m disturbance zone, and 45% assuming a 500-m disturbance zone (Fig. 2). However, the percentage growth of disturbed land area was much lower than for housing growth; on average the proportion of disturbed land area grew only 4% and 18% (100-m and 500-m disturbance zone respectively) from 1937 to 1999. The Northern Highlands exhibited the most pronounced trend of increasing disturbed land area over time, and two of its six townships had more than half of their land area within the 500-m disturbance zone in 1999 (Fig. 2). The Loess Plain, on the other hand witnessed essentially no increase in disturbed land area, but three of the five townships were more than 50% disturbed in 1937.

The relationship between percentage change in housing density versus percent change in disturbed land area is practically linear, as would be expected (Fig. 5). However, the slope of this relationship is far below the 1:1 line, especially in the case of the 500-m disturbance

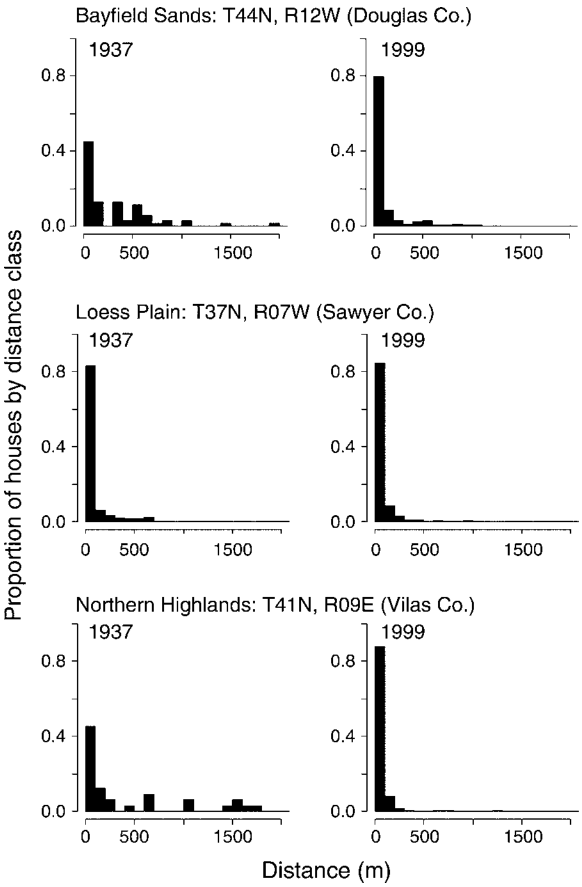

FIG. 3. Frequency distributions of houses by distance to the nearest house in one exemplary township for each ecoregion, comparing 1937 and 1999 distributions.

zone. In the most extreme case, a 1658% increase in the number of houses resulted only in a 204% increase in the disturbed land area.

Due to clustering, the realized footprint of each house was much lower than the maximum of 3.1 and 78.5 ha for the 100-m and the 500-m disturbance zones, respectively (Fig. 6). Only one township in the Bayfield Sands exhibited realized house footprints close to the maximum (T48N, R07W), a township with very few houses (Fig. 2). The general trend was for house footprints to decline over time, but they declined asymptotically, and the strongest decline was between 1937 and 1950.

Houses and lakes

Housing density was many times higher close to lakes than when further away (Fig. 7). This pattern was most pronounced in the Northern Highlands, where housing density within 50 m of lakes reached almost 90 houses/km^2; nearly double the density observed in the other two ecoregions. All three ecoregions exhibited the highest housing density in the 50-m buffer in 1999 and housing density in the 50-m buffer was always the highest in the Northern Highlands, and the Bayfield Sands. In prior decades, however, the Loess Plain exhibited the highest housing density in the 50–100 m buffer.

The Northern Highlands exhibited the highest housing density of the three ecoregions within the 50-m buffer despite the fact that it also had the most land area in this buffer class (4.8% vs. 2.7% and 1.8% in the Bayfield Sands and the Loess Plain, respectively). The fact that more land area close to lakes was available in the Northern Highlands did not result in lower development pressure and thus housing density, but rather the contrary. Of all the houses in the Northern Highlands, more than 40% were within 50 m of a lake in 1937, and this percentage increased to more than 50% by 1960.

Not surprisingly, the comparison of percentage of houses vs. percentage of land area in the different buffers showed strong clustering of houses within the first 50 and 100 m of lakes (Fig. 7). In 1937 the Northern Highlands, Bayfield Sands, and the Loess Plain had 8.6, 4.4, and 1.8 times more houses within 50 m of lakes than would be expected under random distribution.

Houses and land cover

Land cover classes associated with human land use (i.e., urban, barren, agriculture, and grassland) occurred largely within the 500-m disturbance zone (Fig. 8) and were much more prevalent both within the 100-m and the 500-m disturbance zone, than in the area outside these zones (Fig. 9). This is not surprising, but confirms that the majority of human land use occurs in fairly close proximity to houses in northern Wisconsin. Among the natural land cover classes, a higher proportion of forests fell within the disturbance zones (about half) than wetlands (about one-third; Fig. 8). Wetlands contain vegetation and, unlike lakes, were essentially absent within the 100-m disturbance zone, despite being fairly prevalent in the undisturbed land areas. The proportion of the three forest types often differed considerably between disturbed and undisturbed land areas, but there was no clear trend (Fig. 9).

DISCUSSION AND CONCLUSIONS

Our results indicate substantial increases in housing density but only moderate increases in habitat loss between 1937 and 1999. This difference occurs because houses were already clustered in 1937, and this pattern remained largely constant. This is good news from a conservation standpoint, because it limits habitat loss. However, housing clusters were not randomly located, and occurred largely within close proximity to lakes. This is troublesome, because these are important ecosystems for many species that are easily damaged. Our results suggest that in northern Wisconsin the clustering of houses is of less concern for conservation than the question of whether houses are located in

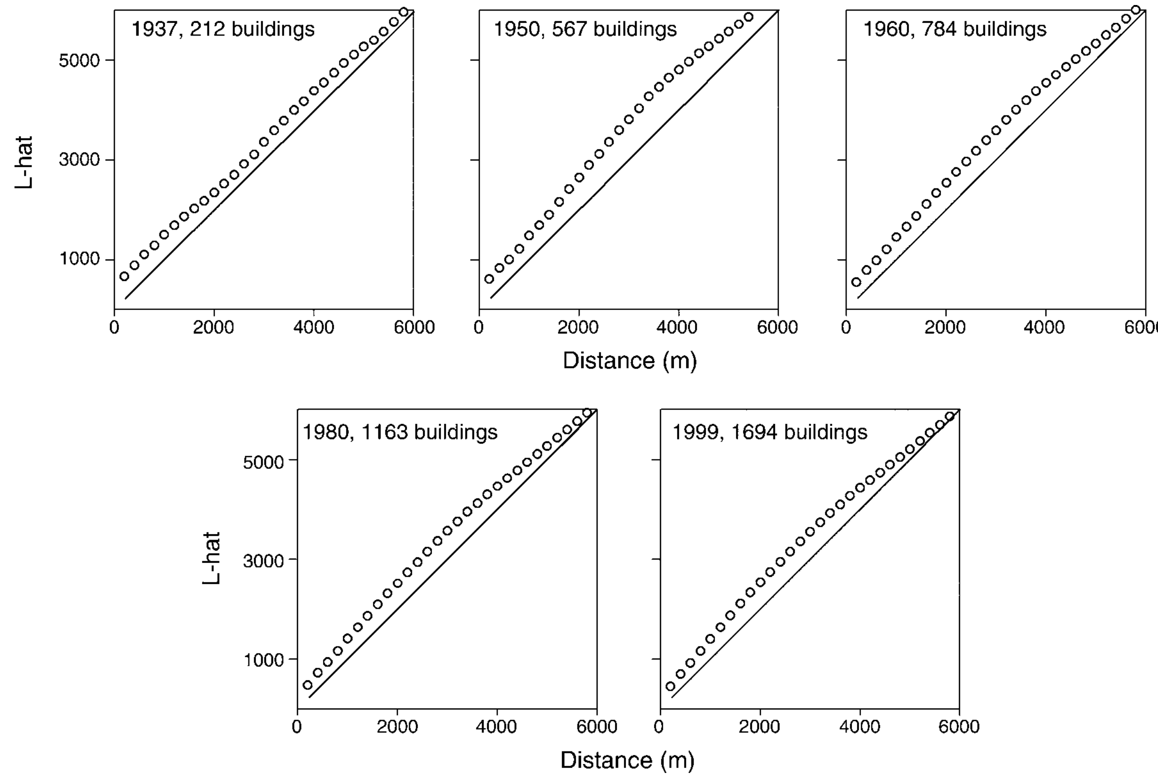

FIG. 4. Spatial patterns of houses in one township (T39N, R11W) over time as measured by Ripley's K test (L-hat) values; values above the 1:1 line indicate a clustered pattern. We show only one township here since results were similar for all other townships.

habitat types that are particularly important for many species.

Housing density increased by 353% over the 60 years studied, and housing growth continued unabated through the most recent time point. Similar growth trends are found throughout the forested regions of the U.S. Midwest (Hammer et al. 2004, Radeloff et al. 2005), and rural areas through the United States that are rich in natural amenities (Theobald 2001, Brown et al. 2005). Such strong housing growth rates are cause for concern because of the known effects of houses on the environment, which include habitat loss and fragmentation, introduction of exotic invaders, higher predation rates by mesopredators and pets, declines in water quality, and generally a loss of biodiversity (Hansen et al. 2005).

In terms of the spatial pattern of houses, we were surprised that houses were already strongly clustered in 1937 and that this pattern remained essentially unchanged through 1999. In general, the national trend in the United States since the 1940s has been toward more dispersed housing (Hobbs and Stoops 2002, Radeloff et al. 2005). In our study area, this trend did not occur at the scale of the townships, and clustered development was and remains common. However, at the regional scale, any housing development in our study area represents dispersion of houses away from cities.

Our results also present strong evidence that the clustering of houses indeed limits habitat loss, and that habitat loss cannot be predicted based on housing density alone. Habitat loss increased much less than the number of houses. This result was surprising because habitat loss as we defined it is strongly related to the number of houses, and the number of houses increased by 353% from 1937 to 1999. Our findings were consistent with previous research (Theobald et al. 1997), which demonstrated that clustered housing in artificial landscapes resulted in lower levels of habitat loss (Theobald et al. 1997, Odell et al. 2003).

Our change analysis highlights the strong legacy effects of early development patterns. Development was already clustered in 1937, and this pattern persisted over time. When new houses were developed, they were generally placed within the vicinity of existing houses, and nearest-neighbor distances decreased. One reason for this may be easier road access in areas where houses had been built previously (Hawbaker et al. 2006). Such legacy effects are an important consideration when placing new houses (and roads) in frontier landscapes. Patterns established early are likely to persist over a very long time.

The reason why clustered development was so prominent in our rural study area is most likely homeowners' preference for living near lakes. For

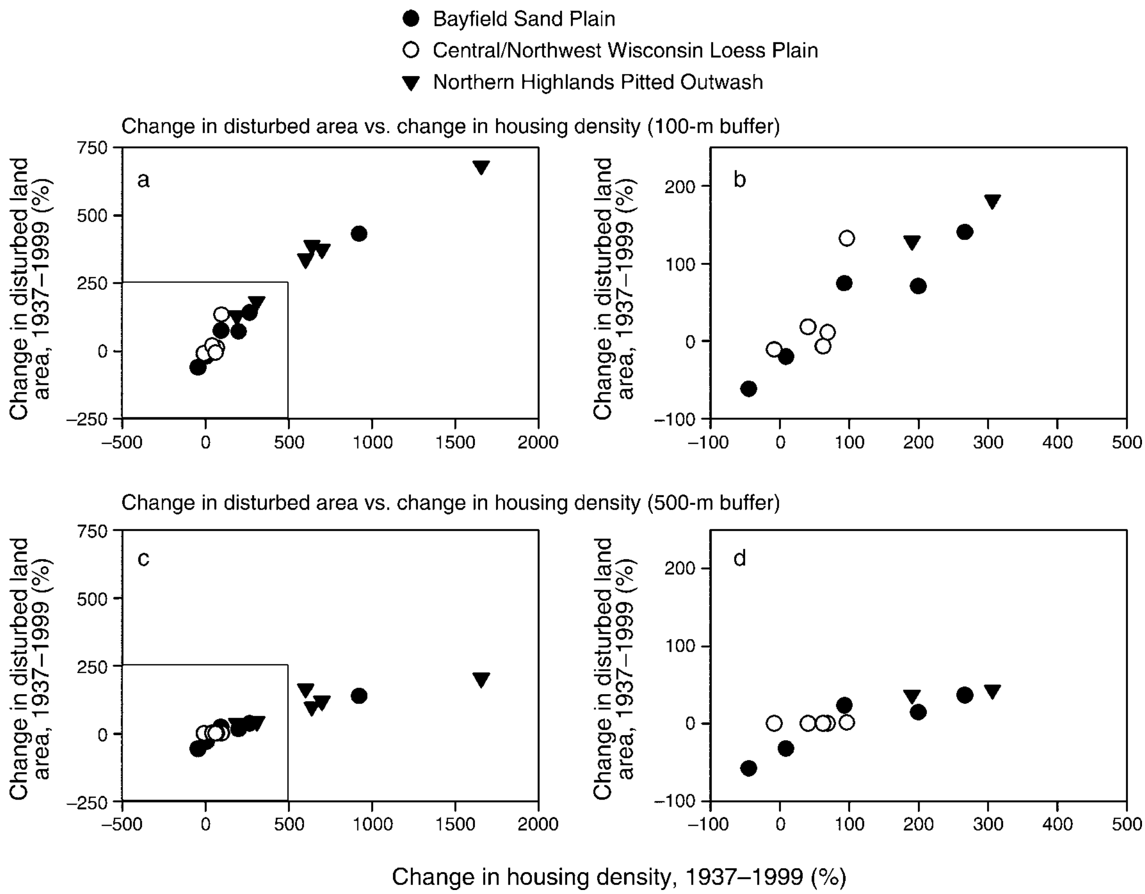

FIG. 5. Percentage change in disturbed area vs. the percentage change in housing density, assuming a 100-m disturbance zone (top row) and a 500-m disturbance zone (bottom row). Graphs on the left show the full range of values; graphs on the right depict only townships between –100% and 500% housing growth (expanded from boxes in the left-hand graphs).

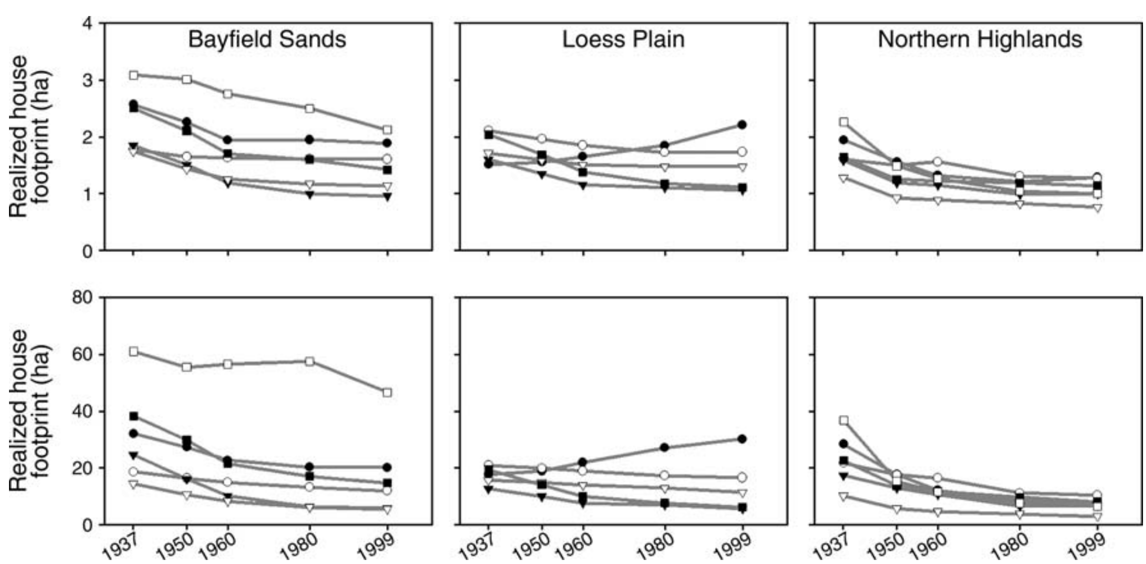

FIG. 6. Realized house footprints, i.e., the ratio of the number of houses divided by the total land area of all disturbance zones, assuming a 100-m disturbance zone (top row), and a 500-m disturbance zone (bottom row), for each township in the three ecoregions: Bayfield Sands (left column), Loess Plain (center column), and Northern Highlands (right column). See Fig. 2 for a legend for the township symbols.

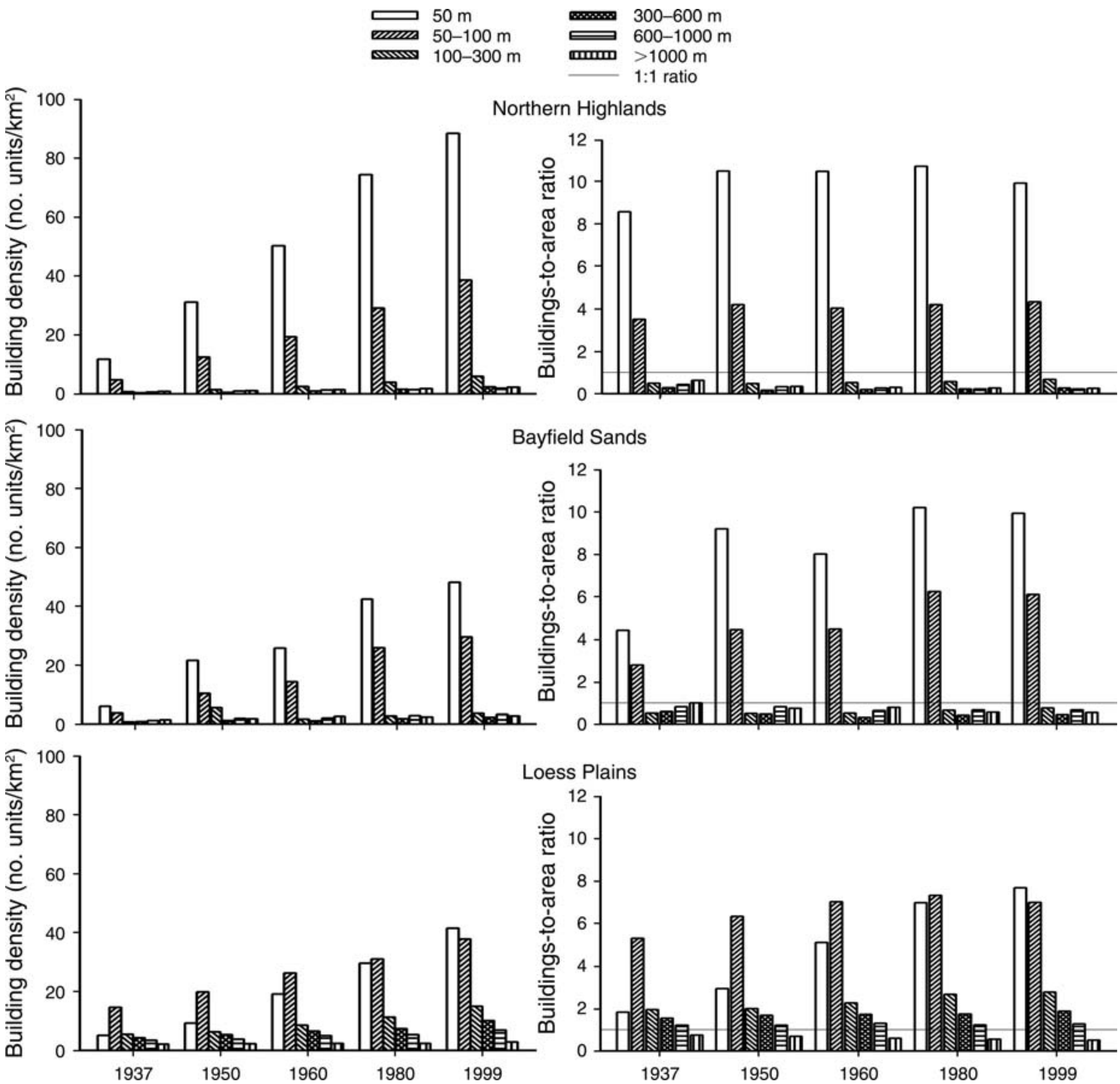

FIG. 7. Housing density at increasing distances from lakes (left-hand column) and the houses-to-area ratio in a given buffer (right-hand column) from 1937 to 1999. The houses-to-area ratio in a given buffer is the division of the percentage of all houses in that buffer by the percentage of the land area in that buffer. For example, if a given buffer contains 50% of all houses in the township, but only 25% of the land area, the houses-to-area ratio would be 2. Houses-to-area ratios >1 indicate a clustering of houses in that buffer.

example, in the Northern Highlands 40% of the houses were within 50 m of a lake, a zone that represents only 5% of the terrestrial area. Interestingly, though, the likelihood that houses are located within 50 m of a lake has somewhat declined between 1980 and 1999 in the Northern Highlands and the Bayfield Sands. People may avoid high housing densities now common along lakeshores, maybe because they prefer a less dense setting, because increasing costs for lakeshore properties force them to build elsewhere, or because zoning restrictions limit where new houses can be built.

The development along lakeshores is viewed with concern among citizens and land use planners in northern Wisconsin (Stedman and Hammer 2006). The value of lakes as a natural amenity diminishes when shores are too intensely developed, and their ecological functioning is compromised as well. Strong housing growth along lakes has resulted in numerous zoning ordinances requiring a minimum shoreline length for properties where new development occurs, as well as a minimum distance from the shoreline at which a house can be placed. In contrast to what has been proposed in other parts of the United States, all of these zoning ordinances attempt to disperse houses, and avoid further clustering near lakes. The strong clustering that we observed is thus not the result of zoning, but rather

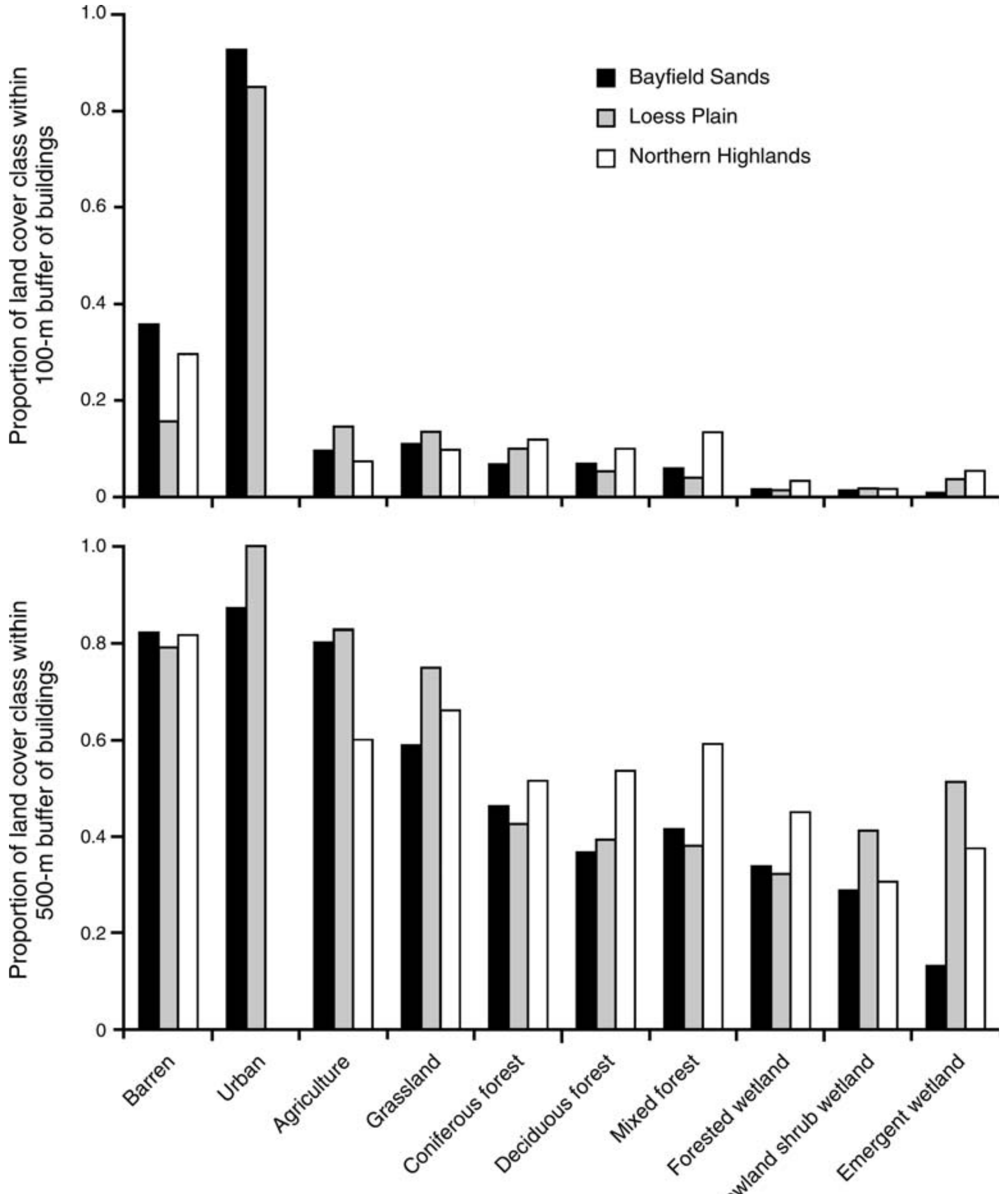

FIG. 8. The proportion of the area of each land cover class affected by 100-m disturbance zones (top) and by 500-m disturbance zones (bottom).

occurred either before zoning regulations were implemented, or despite of them.

The fact that houses are clustered is good news for conservation, because it limits habitat loss, but the location of houses in northern Wisconsin is highly problematic, for many reasons. Lakeshores provide a critical habitat for both terrestrial and aquatic species, and are essential to maintain viable populations of numerous species that depend on them during critical stages of development. Housing development along lakeshores changes bird communities to the detriment of insectivores and ground-nesting birds, instead favoring seed-eaters and deciduous tree nests (Lindsay et al. 2002). Lakeshore development also causes lower green frog (*Rana clamitans melanota*) abundance (Woodford and Meyer 2003), and local extinctions of wood turtles (*Clemmys insculpta*) (Garber and Burger 1995). Houses along lakeshores also affect the lakes themselves. Woody debris in the littoral zone is less abundant (Jennings et al. 2003), and the destruction of riparian vegetation and decrease of coarse woody debris imperils macroinvertebrate and fish assemblages (Christensen et al. 1996), and diminishes the richness of aquatic plant communities (Hatzenbeler et al. 2004).

In summary, what our study suggests, is that clustering development may be of secondary importance

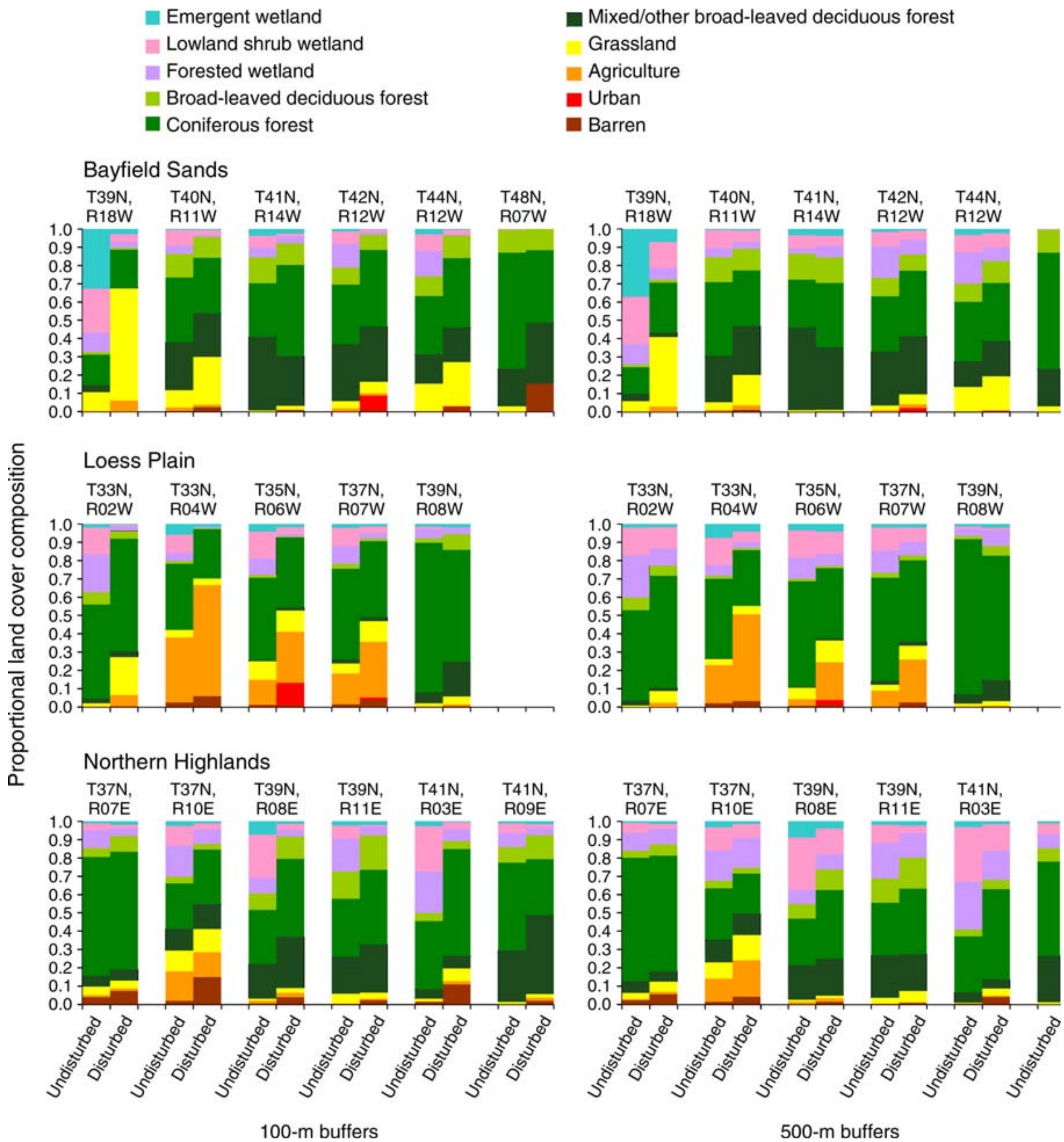

Fig. 9. Proportional land cover composition inside (disturbed) and outside (undisturbed) the 100-m disturbance zone (left column) and the 500-m disturbance zone (right column).

for conservation, and the main question is where new houses are located. Yes, clustered development is more preferable than dispersed housing growth, but clustered development has major effects on smaller areas due to the high density of houses. If the trend toward the development of all areas near lakes persists, there is a danger of losing what is particularly important habitat. Thus, in order for clustered development to reduce the potential impacts of housing development, clusters must be located away from habitats that are particularly sensitive and important.

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