Human Demographic Trends and Landscape Level Forest Management in the Northwest Wisconsin Pine Barrens

Volker C. Radeloff, Roger B. Hammer, Paul R. Voss, Alice E. Hagen, Donald R. Field, and David J. Mladenoff

ABSTRACT. The effects of landscape pattern on forest ecosystems have been a recent focus in forest science. Forest managers are increasingly considering landscape level processes in their management. Natural disturbance patterns provide one baseline for such management. What has been largely ignored is the pattern of human habitation patterns (i.e., housing), on landscapes. The objective of this study is to discuss landscape level management options for the northwest Wisconsin Pine Barrens based on both landscape ecology and the human demographics of the region. Using the 1990 U.S. Decennial Census we examined current housing density, seasonal housing unit concentration, historic housing density change and projected future housing densities. These data were related to land cover and land ownership data using a GIS. Housing density increase was particularly pronounced in the central Pine Barrens, an area where seasonal housing units are common. Lakes and streams were more abundant in areas that exhibited highest growth. Within national forest lands, 80% of the area contained no housing units. In contrast, only 12% of the area in small private land ownership contained no housing. These results are integrated with previous studies of presettlement vegetation and landscape change to discuss landscape level management suggestions for the Pine Barrens. For. Sci. 47(2):229–241.

Key Words: Census data, demographics, ecosystem management, landscape ecology, Wisconsin Pine Barrens.

Whatever progress we make with the application of the physical, biological and mathematical sciences to landscapes, it will amount to little unless we can incorporate the impacts of human activity—Ian Noble (1996, p. 175).

Forest science and forest management increasingly embrace the notion that scales broader than sampling plots or single stands are required to understand and manage forest ecosystems (Crossley 1996, Toman and Ashton 1996, Baskent and Yolasigmaz 1999). Landscape patterns can have strong effects on ecological processes (Turner 1989). This makes it important to study landscape patterns created both by natural disturbances, such as fire, and settlement patterns on the land, such as housing density, to understand their roles in forest ecosystems (Romme 1982). Landscape pattern in managed landscapes is often significantly different than in unmanaged landscapes (Mladenoff et al. 1993, Wallin et al. 1996). Forest management has a strong effect on landscape pattern (Franklin

V.C. Radeloff, Department of Forest Ecology and Management, 1630 Linden Dr., University of Wisconsin–Madison, Madison, Wisconsin 53706—Phone: (608) 263-4349; Fax: (608) 262-9922; E-mail: radeloff@facstaff.wisc.edu. R.B. Hammer and A.E. Hagen, Department of Rural Sociology, University of Wisconsin—Madison; D.R. Field and D.J. Mladenoff, Department of Forest Ecology and Management, University of Wisconsin–Madison; P.R. Voss, Department of Rural Sociology, University of Wisconsin—Madison, and International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

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and Forman 1987, Spies et al. 1994, Gustafson and Crow 1996), but traditionally these effects have not been taken into account when planning harvests. Natural disturbance patterns have been endorsed as potential guidelines for forest management at the landscape level (Attiwill 1994, Mladenoff et al. 1994, Bergeron and Harvey 1997, Schnitzler and Borlea 1998). For example, extensive clearcuts may resemble natural openings in the boreal forest —where crown fires are common—for some, but not all ecological processes (Bondrupnielsen 1995, Sturtevant et al. 1996, Mönkkönen 1999, Niemela 1999). What is largely lacking in these studies is a discussion of the human dimension of landscape level management. We define landscape level management here as forest management that attempts to maintain or reconstruct broad scale landscape patterns, such as habitat connectivity or large patches of mature forest. Landscape level management operates by definition in large areas, which in most cases will be at least partly settled. Landscape level management needs to be based on both, the spatial patterns of forests and disturbance processes as well as the patterns of settlement and their change over time.

This is not to say that the strong influences of settlements and human population growth on forest ecosystems are not recognized (Foster 1992, Ehrlich 1996, Matlack 1997), but most studies address these questions at regional or global scales (Harrison 1991, Meyer and Turner 1992, Dale et al. 1993, Kummer and Turner 1994, Fischer and Heilig 1997, Mather et al. 1998, Pfaff 1999). Rarely are these influences studied at the landscape level, a scale that may be more appropriate for identification of causal relationships and more relevant for forest managers. At the landscape level, human population density has been correlated with wolf occurrence in Wisconsin (Mladenoff et al. 1995), land cover change in several U.S. landscapes (Turner et al. 1996) and local plant extinction in Britain (Thompson and Jones 1999). Residential development has detrimental effects on forest-dwelling migratory songbirds (Friesen et al. 1995). There is also a strong relationship between socioeconomic factors and biodiversity (Machlis and Forester 1996). Settlement patterns in the Central Amazon threaten faunal biodiversity (Dale et al. 1994), and different land development scenarios pose varying risks to biodiversity (White et al. 1997).

Although the U.S. population has been predominantly urban/suburban for more than a century, urban residents have also expressed a preference for living in more rural areas. Public opinion polls dating back to the 1940s have demonstrated the desire on the part of large portions of adults living in cities to live in nonmetropolitan areas (Fuguitt and Zuiches 1975), and these attitudes have remained relatively unchanged up to the present (Fuguitt and Brown 1990, Brown et al. 1997). After decades of stability and decline, population growth in northern Wisconsin proceeded at a relatively rapid pace throughout the "turnaround" decade of the 1970s, a decade marked by faster growth in nonmetropolitan counties than in their metropolitan counterparts across the United States (Fuguitt 1985). Although this nonmetropolitan turnaround subsided in the early 1980s, there is evidence that nonmetropolitan counties experienced somewhat similar growth patterns in the late 1980s and at least into the early 1990s (Beale and Fuguitt 1990, Johnson and Beale 1994, Long and Nucci 1999). Although growth in Wisconsin's northern tier of counties including the Pine Barrens has partially subsided since the 1970s, selected "recreational areas" continue to grow at annual rates exceeding the state average. Recreational amenities have long been recognized as an important influence on migration to nonmetropolitan areas (Marans and Wellman 1978, Geoghegan et al. 1997). The impact of new growth has not been uniform across Northern Wisconsin, rather, it has focused in those subregions rich in environmental amenities, such as freshwater lakes and mature secondary forests (Voss and Fuguitt 1979). These residential preferences (Luttik 2000) and population trends are important factors for landscape scale management of forest resources.

We suggest that further research is needed to integrate the spatial pattern of human settlements with ecological data at the landscape level. The lack of methods for accomplishing this may be one reason landscape level management is still in its infancy. This study provides one such example, integrating U.S Decennial Census housing density data with ecological research to identify landscape level management options in the northwest Wisconsin Pine Barrens.

Study Area: The Northwest Wisconsin Pine Barrens

Current management and conservation concerns in the Pine Barrens area in northwestern Wisconsin (Figure 1) demonstrate the necessity of landscape level forest management. Presettlement landscape patterns of this area were largely shaped by fire disturbance, which created large openings where crown fires occurred and savannas where ground fires were frequent (Radeloff et al. 1998). These landscape patterns have changed since European settlement beginning in the 1860s. Timber harvest, farming, reforestation, and fire suppression have resulted in denser forest cover (Radeloff et al. 1999). Resource management agencies are attempting to restore elements of the presettlement landscape patterns (Radeloff et al. 2000b). In the following section, a brief overview of the region, the presettlement landscape and the current management problems will be presented.

Located on a glacial outwash plain, and covering about 450,000 ha, the Pine Barrens region is a unique ecosystem in northwestern Wisconsin (Murphy 1931) (Figure 1). The coarse, sandy soils are prone to drought, and fire is an integral disturbance process in the natural ecosystem. Fire regimes in the Pine Barrens varied before European immigrant settlement of the area. Within the region, there were at least three distinct subregions during presettlement times (Radeloff et al. 1999)(Figure 1). The southern Pine Barrens were shaped by frequent but low intensity ground fires, creating savannas with low tree density but often large red pine (*Pinus resinosa*) and burr oak (*Quercus macrocarpa*) (Radeloff et al. 1998). The central Pine Barrens exhibited very frequent, high intensity crown fires in stands composed almost exclusively of jack pine (*P. banksiana*). Fires created large openings, and

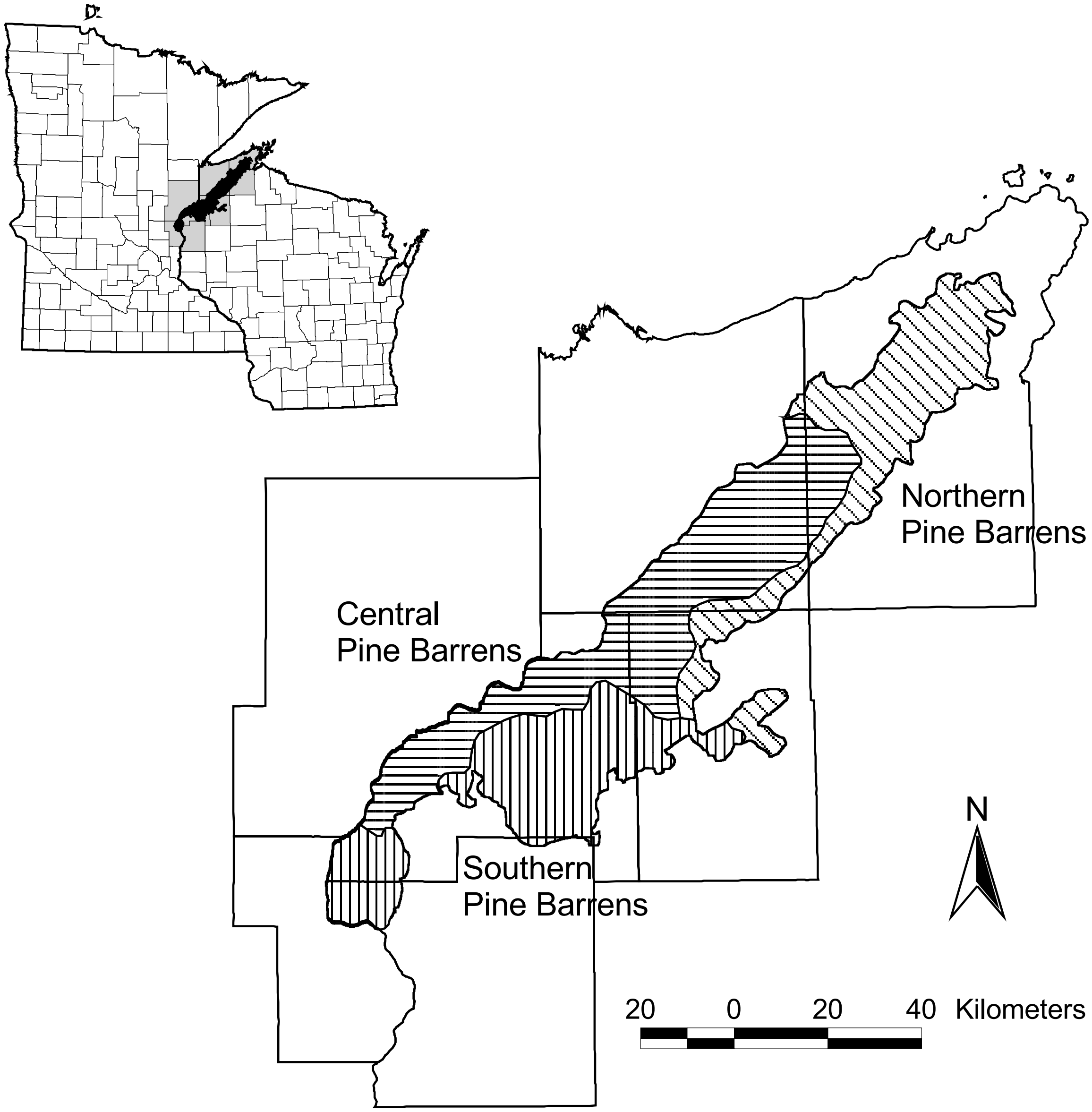

Figure 1. The Pine Barrens region in northwestern Wisconsin and the surrounding counties that were included in our analysis.

even-aged jack pine regeneration was common in these areas. The northern Pine Barrens also exhibited high intensity crown fires, but their frequency was lower than in the central Pine Barrens. This resulted in mixed pine forest containing white (*P. strobus*), red, and jack pine as well as some red oak (*Q. rubra*). European settlers altered the Pine Barrens beginning in the 1860s. In the 19th century, logging and farming removed forest cover almost entirely. Since the 1930s, reforestation and fire suppression have increased forest cover, leading to denser forest cover than found before European settlement (Radeloff et al. 1999).

The decrease of open habitat has been detrimental to an array of species adapted to openings previously created by fire. Grassland bird populations declined during the second half of the 20th century, and certain open habitat species, such as the Karner Blue butterfly, have been listed as endangered and have required special management actions. Landscape pattern (i.e., the spatial allocation of openings) is a crucial aspect of the habitat requirements for these species. For example, the number of grassland bird species in an opening is positively correlated with its size (Niemuth 1995).

The decline of many open habitat species prompted the Wisconsin Department of Natural Resources (WDNR) to investigate options for landscape level management (Borgerding et al. 1995). Two workshops (in 1993 and 1999) attended by WDNR officials, university researchers, regional planning commission members, and local government officials were conducted to share results from various scientific studies in the area with resource managers and the general public. Initial steps are currently being taken to implement adaptive management (G. Bartelt, WDNR, 1999, personal communication). As a result of these workshops, as well as further scientific study, the WDNR identified the lack of open habitat, and especially of large openings, as one of the major management problems in the Pine Barrens. The WDNR is currently seeking input from the scientific community to assist in developing feasible landscape management scenarios (B. Moss, WDNR, 2000, personal communication).

Study Objective

Previous research provided ecological information for landscape level management, such as presettlement vegetation pattern, disturbance regimes, and historic landscape change, in the Pine Barrens (Radeloff et al. 1998, 1999, 2000b, 2000c). This study integrates this ecological information with (a) 1990 housing density, (b) concentrations of seasonal housing, (c) historic housing densities since 1940 and (d) projected future housing densities to 2020. Housing data is integrated with land cover and land ownership data to examine correlation and possible causal relationships with housing growth. The objective of this study is to discuss landscape level management options in the Pine Barrens by analyzing the spatial pattern of housing density and its change over time in the context of the disturbance pattern and vegetation composition in the presettlement landscape.

Methods

The 1990 Census of Population and Housing

The analysis of housing density in the Pine Barrens is primarily based on the 1990 Census of Population and Housing conducted by the U.S. Census Bureau (1992). The 1990 census was the first ever to be released with a corresponding nationwide digital map, permitting detailed spatial analysis. The smallest geographic unit in the census is the census block, which is defined by both physical boundaries, such as railroad tracks, roads, and lake shores and political boundaries such as property lines and municipal boundaries. The size and shape of census blocks can vary widely, largely based on housing unit density with the smallest units located in areas of high density.

In the U.S. Decennial Census, every household is required to fill out the so-called "short form" questionnaire, where only basic questions about housing units and households are asked. A national sample of about 17% of households (with a larger sample in rural areas) fills out the so-called "long form" questionnaire, containing more detailed housing, social, and economic questions. Because of concerns about confidentiality and sampling error, census data from the "long form" questionnaire are not released for census blocks but only for the more aggregated census block groups and other larger units of census geography.

Given its availability, we analyze overall housing density and seasonal housing density in 1990 at the census block level. Since the detailed housing questions are only asked in the "long form" questionnaire, we only analyze historic and projected future housing densities at the block group level. Housing densities in 1990 (units/km^2) were calculated by dividing the number of housing units by the land area of the census block.

We examine seasonal/recreational housing separately from the overall housing stock and housing density. Although the differences in attitudes and behaviors among seasonal and permanent residents are not well understood, seasonal homeowners, attracted by the area's recreational and scenic amenities, may differ markedly from permanent residents in their attitudes towards forest management. For instance, one study of attitudes toward economic development in a single county of northern Wisconsin (not one of the Pine Barrens counties) found that permanent residents were less supportive of land use planning than were seasonal residents, even when controlling for social and economic characteristics (Green et al. 1996). Seasonal housing units are unoccupied units determined to be for seasonal, recreational, or occasional use. As defined by the U.S. Census Bureau, seasonal units include those for summer or winter sports or recreation, such as beach cottages and hunting cabins, as well as time-sharing or interval ownership condominiums. Like vacancy status itself, and other characteristics of vacant units, seasonal use of units is determined by census enumerators obtaining information from landlords, owners, neighbors, rental agents, and others (U.S. Census Bureau 1992, p. B-49). We identified seasonal housing concentration areas as those where seasonal housing density was high and/or where the majority of housing units was seasonal (Table 1).

Our analysis of the census data included not only the area of the Pine Barrens itself, but also the remainder of five Wisconsin counties that lay partly in the Pine Barrens as well as two neighboring Minnesota counties. We opted to include these areas to provide a more complete view of the settlement patterns that affect the Pine Barrens. Hereafter, the entire area under investigation will be referred to as the Pine Barrens counties.

Historic Housing Density and Future Projections

The 1990 census data includes information on the decade of origin of a housing unit, as reported by the occupant. By itself, data on the decade of origin of housing units enumerated in the 1990 census underestimates historic housing densities. For example, a housing unit established in 1942 and demolished in 1986 is not included in the 1990 census. Therefore, ancillary information is required to obtain better estimates of historic housing densities. The total number of housing units per county is known for every decade from previous censuses. We used this information to adjust the data on the year of origin of housing units in the 1990 census.

A_j^{t-1}, the net number of housing units in county j at time $t-1$ missing from the 1990 census, is defined as:

$$A_j^{t-1} = C_j^{t-1} - H_j^{t-1} \quad (1)$$

where C_j^{t-1} is the estimated number of housing units in county j at time $t-1$ based on census taken at time $t-1$, and H_j^{t-1} is the estimated number of housing units in county j at time $t-1$ based on the 1990 census.

Table 1. The classification of seasonal housing concentration areas based on the seasonal housing density and the relative importance of seasonal housing compared to all housing.

Seasonal housing density (units/km^2)		Percentage seasonal housing: Low < 33	Medium > 33–66	High > 66
Low	0 – 1	Class 5	Class 4	Class 4
Low	> 1 – 2	Class 5	Class 4	Class 2
Medium	> 2 – 3	Class 5	Class 2	Class 2
High	> 3 – 4	Class 3	Class 1	Class 1
High	> 4	Class 3	Class 1	Class 1

Using the ratio of A_j^{t-1} and H_j^{t-1} as the adjustment factor we calculated $\hat{H}_{ij}^{t-1}$, the adjusted housing density in block group i of county j at time $t-1$ as follows:

$$\hat{H}_{ij}^{t-1} = H_{ij}^{t-1} + \left[H_{ij}^{t-1} \frac{A_j^{t-1}}{H_j^{t-1}} \right] \quad (2)$$

where H_{ij}^{t-1} is the estimated number of housing units in block group i of county j at time $t-1$ based on 1990 census.

Using this method, adjusted block group housing densities were calculated for years ending in zero (census years) for every decade starting with 1940. These data allowed calculation of growth rates for every decade. These estimates of the historic growth in housing densities were then used to project future housing density, assuming that growth rates remain unchanged. To project future housing densities, we applied the average growth rate of a census block group between 1940 and 1990 to the 1990 census data to derive housing densities for 2000, 2010 and 2020.

Integrating Land Cover and Land Ownership Information

Housing development is strongly influenced by two factors, land cover ("Where would I like to build my house?") and land ownership ("Where am I allowed to build my house?"). Census data was related to both of these factors in order to better understand development in the Pine Barrens counties.

A previous study quantified the relationship between land cover data and 1990 housing density (Radeloff et al. 2000a). The current study examines the relationship between land cover and housing density growth over time at the census block group level. The overall increase in housing density between 1940 (adjusted) and 1990 was divided into five housing density growth classes. Class 1 contained census block groups with growth <=1 unit/km and the remaining census block groups were divided so that each class represented an equal area. Land cover data were incorporated using a Landsat satellite image classification based on a 1987 Thematic Mapper scene and several Multispectral Scanner images (Wolter et al. 1995). Using the approach outlined in Radeloff et al. (2000a), the average proportions of land cover classes for each housing density growth class were summarized. Using equal area class boundaries for the census block groups ensured that the estimates of land cover class proportions represent areas large enough to provide robust results.

Land ownership information was incorporated using a GIS coverage provided by the Wisconsin Department of Natural Resources. Private industrial forest holdings were added as described by Mladenoff et al. (1995). Using these data (Figure 2) we calculated the relative abundance of five land ownership classes (national forest, state land, county forest, private industrial forest holdings and small private landowners) for each of the 1990 housing density classes (Figure 3a) at the census block level. Land ownership information was only available for the Pine Barrens itself, and this analysis could not be conducted in the remainder of the Pine Barrens counties.

Results

1990 Overall Housing Density and Seasonal Housing Focus Areas

The 1990 overall housing densities in the Pine Barrens counties reveal several patterns (Figure 3a). As a general trend, housing densities increase from Northeast to Southwest. High density concentrations of housing units are widely dispersed across the region and often occur along lake shores. Medium housing densities are more common south and west of the Pine Barrens, due to the proximity of the Minneapolis-St. Paul and the Duluth-Superior metropolitan areas. In these areas the spatial pattern of housing unit density is more homogeneous.

Seasonal housing units, a subset of all housing units, show a different spatial pattern (Figure 3b). Seasonal housing density is higher in the Pine Barrens itself than in the surrounding areas (Figure 3b). Concentrations of high seasonal housing density especially occur in the central Pine Barrens. A second important aspect of seasonal housing densities is their relative contribution to overall housing densities. Areas where nearly all the housing units are seasonal are concentrated in the southern and central Pine Barrens and in some neighboring areas both to the West and East of the central Pine Barrens (Figure 3c). The integration of seasonal housing density and the percentage of seasonal housing units allows identification of seasonal housing concentration areas (Figure 3d), where both seasonal housing density is high and the majority of the housing units are seasonal.

Historic Housing Densities and Future Projections

The adjusted housing densities between 1940 and 1990 reveal a strong increase in housing densities particularly between 1970 and 1990 (Figure 4). This is especially the case in the southern Pine Barrens, which experienced a significant increase during the 1980s. The northern and central Pine Barrens exhibited relatively low housing densities up to 1990.

The projections of future housing densities are based on a linear extrapolation of historic rates of increase and show, therefore, similar spatial pattern (Figure 5). The strongest increase in housing density between 2000 and 2020 is expected to occur in the southern and central Pine Barrens. The areas south of the Pine Barrens are expected to experience less of an increase. This is due to the fact that these areas already contained medium housing density levels in 1940 and did not increase as dramatically as the southern and central Pine Barrens. The central and southern Pine Barrens are expected to "catch up" with the more densely settled areas along their southern boundary. This represents an expansion of the area influenced by the Twin Cities metropolitan area.

Housing Density, Land Cover, and Land Ownership

The relationship between 1990 housing density and land cover data at the census block level was identified in a previous study (Radeloff et al. 2000a). For example, the relative abundance of water was three times higher in areas in the highest housing density class compared with lowest housing density class. Expanding on this research, this study

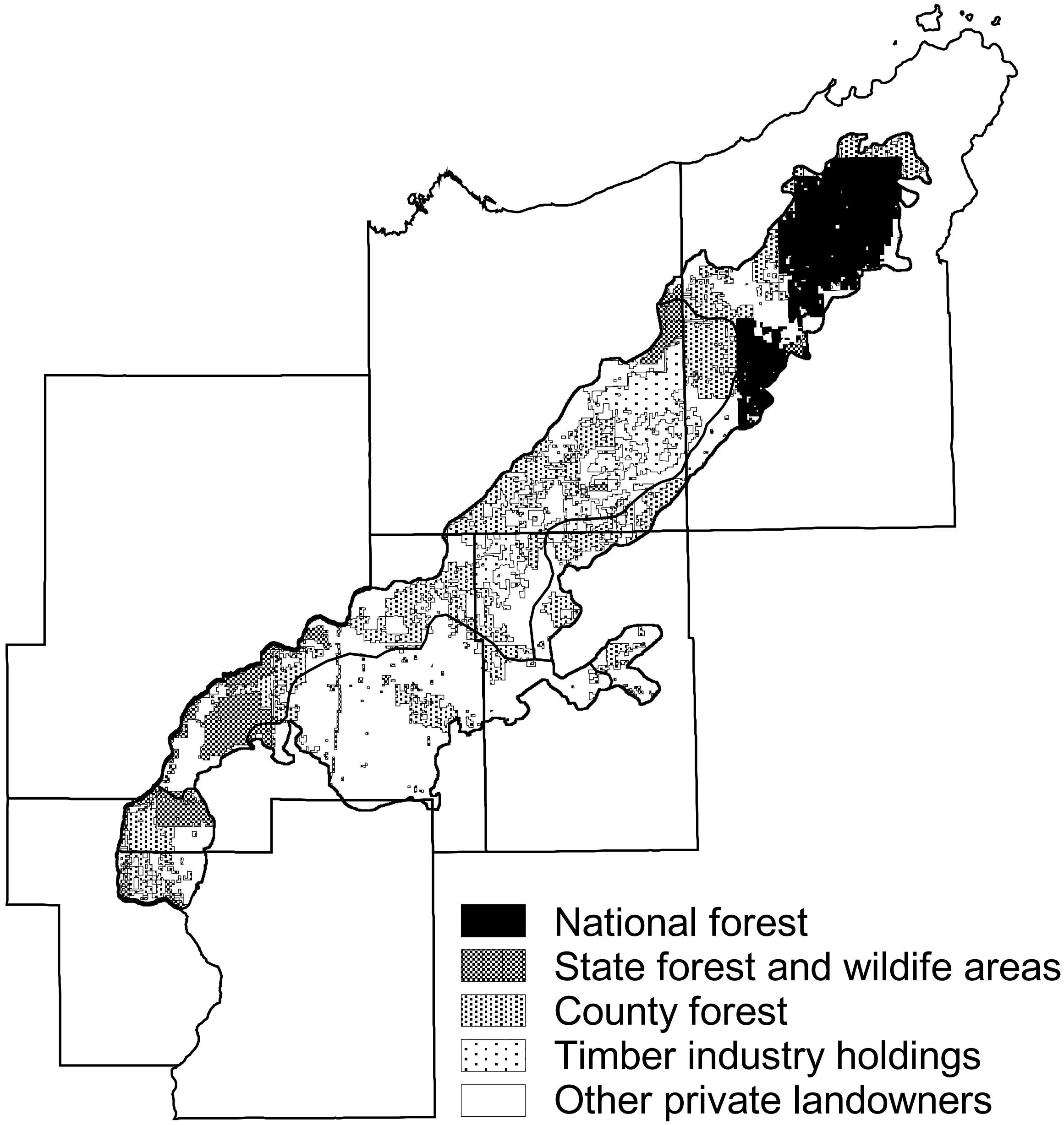

Figure 2. Land ownership pattern in the Pine Barrens. Data courtesy of the Wisconsin DNR.

examines the relationship between housing density growth and land cover (Figure 5). Although housing density declined between 1940 and 1990 in a limited area (421 ha), none of it is found in the Pine Barrens itself and is therefore left out of the discussion and figures.

The four housing density growth categories represent housing unit growth during the period ranging from low growth in category one (growth rate < 2.17) to high growth in category four (growth rate > 3.924). Surface water bodies are relatively more abundant in areas that exhibited the highest growth. This corresponds to the high housing density blocks surrounding lakes. The same trend is found for pine forests and to a lesser degree other conifer forests. In contrast, areas classified as grass, a land cover class that represents pastures as well as agricultural fields, are most abundant where the least growth occurred. These patterns may reflect people's preferences when selecting the location of new houses (Sullivan 1994).

Another factor of the housing density growth pattern is land ownership, which limits the location of new residential development. We examined both the relative abundance of the different land ownership classes within a given housing density class (Figure 6a) and of different housing density classes within each land ownership class (Figure 6b). Most of the area with no housing units (Class 0) is in public ownership, and the relative abundance of public lands rapidly decreases with increasing housing densities, comprising less than 15% of density classes 3 through 5 (Figure 6a). Small, private land ownership dominates housing density classes 2–5, and to a lesser extent class 1. Census blocks that contain water are also predominantly within areas of small private land ownership. The state of Wisconsin is the second most important owner of "water blocks," possibly due to wildlife management complexes that contain extensive wetlands in the southern Pine Barrens. The strong effect of public land ownership becomes

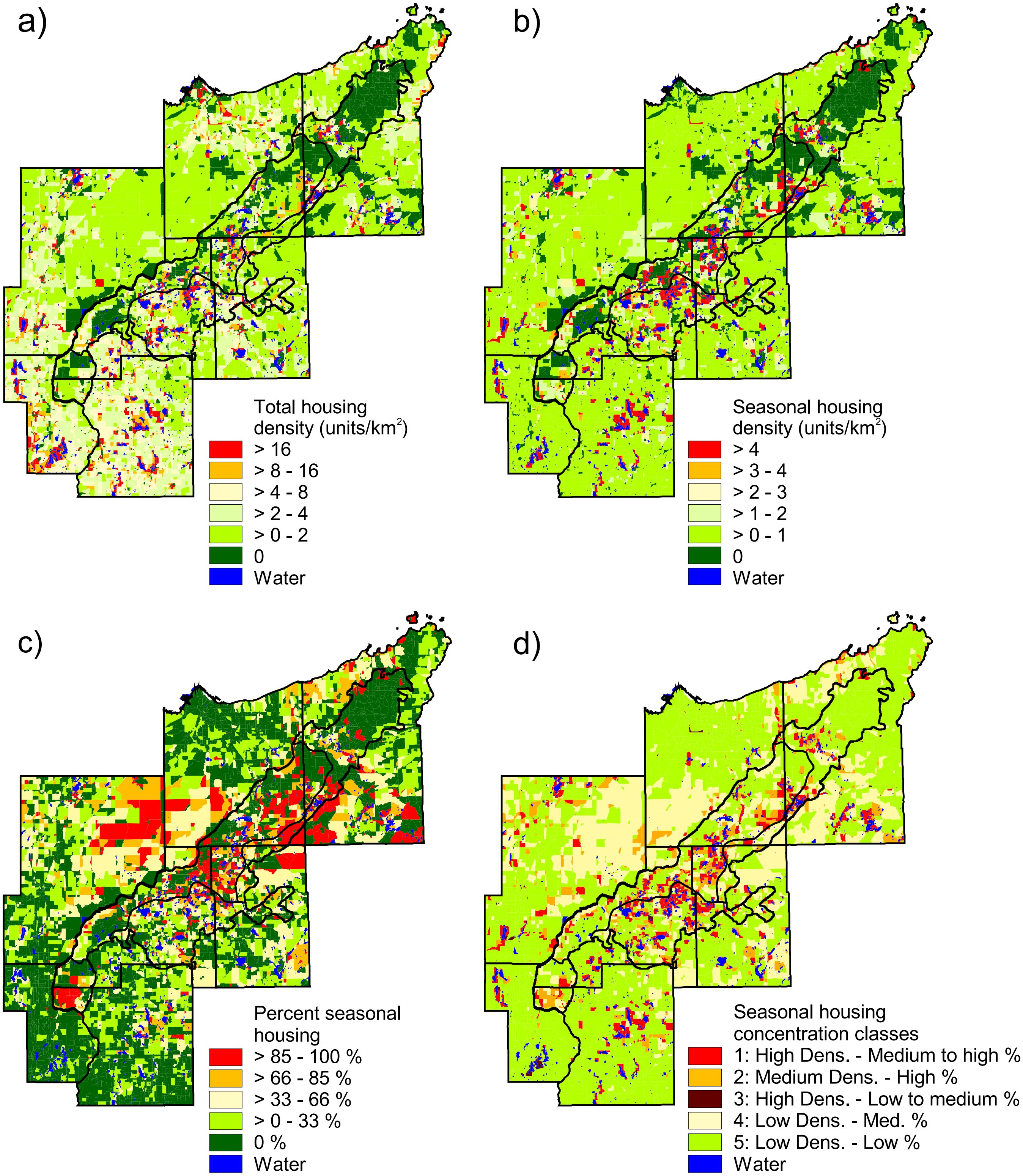

Figure 3. (a) The 1990 overall housing density in the Pine Barrens counties. The Pine Barrens itself is outlined in blue. Spatial pattern of seasonal housing in the 1990 census; (b) seasonal housing densities, (c) percentage of seasonal housing units relative to all housing units, and (d) seasonal housing concentration areas. The Pine Barrens itself is outlined in blue.

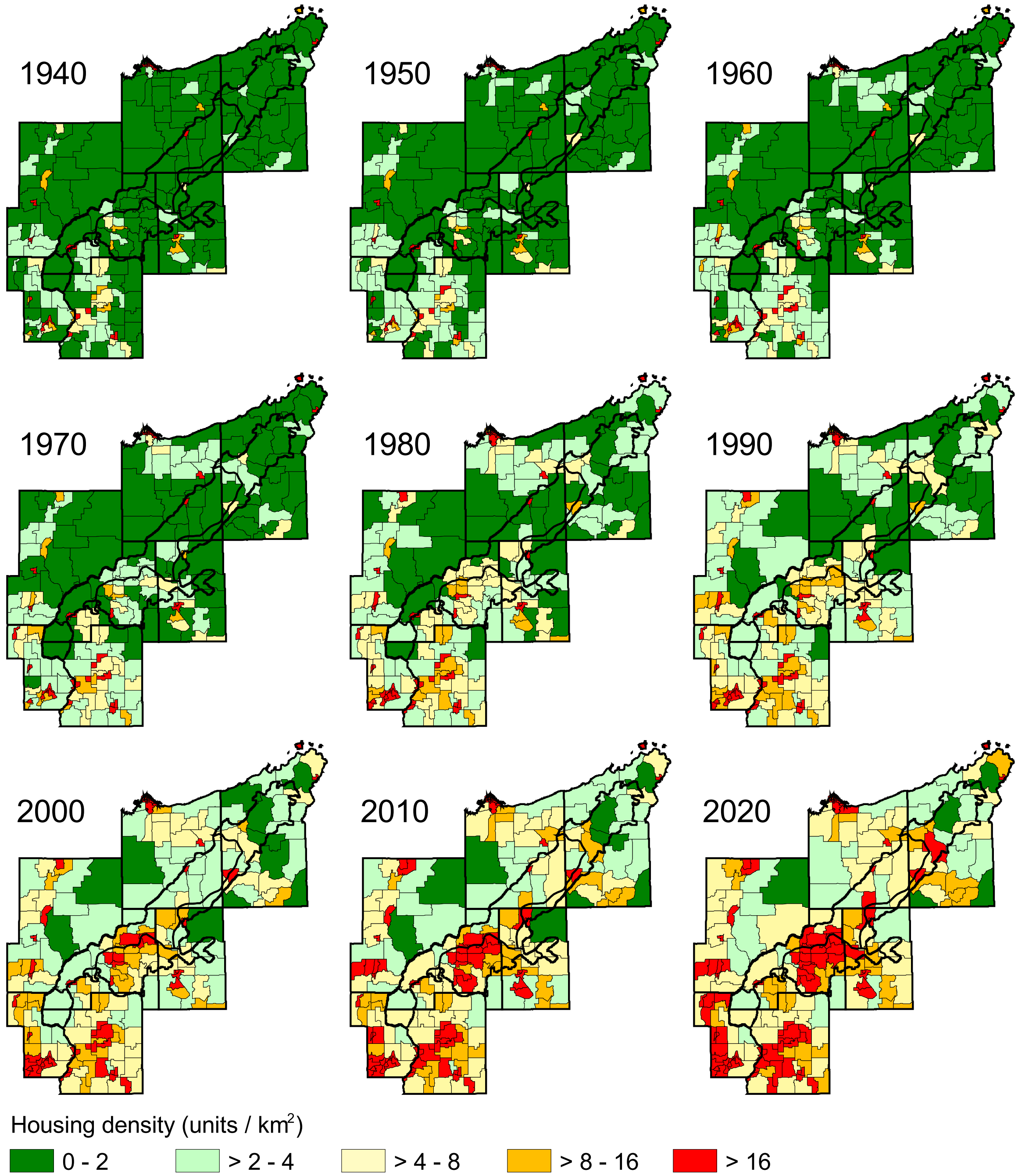

Figure 4. Adjusted historic housing density (1940–1980), current housing density (1990) and projected future housing densities (2000–2020) in the census block groups of the Pine Barrens counties. The Pine Barrens itself is outlined in blue.

even more apparent when examining housing densities within each land ownership class (Figure 7b). Within the national forest lands, 80% of the area contains no housing units. In contrast, only 12% of the area in small private land ownership contains no housing units.

Discussion

The analysis of the 1990 census data reveals a strong spatial pattern in overall housing density and its growth. We have identified seasonal housing concentration areas, and projected future housing unit densities after adjusting and analyzing historic trends, and related growth rates to land cover and ownership. What do these results suggest for landscape level forest management of the Pine Barrens region? In the following we discuss different landscape level management priorities for each of the three subregions within the Pine Barrens.

The analysis of the presettlement Pine Barrens landscape provides important background information for management decisions (Radeloff et al. 1998, 1999). We outlined above the need for more open habitat in the Pine Barrens because this habitat type diminished as a result of reforestation and fire suppression since the 1930s. However, we do not advocate restoring the Pine Barrens landscape to a specific point in time.

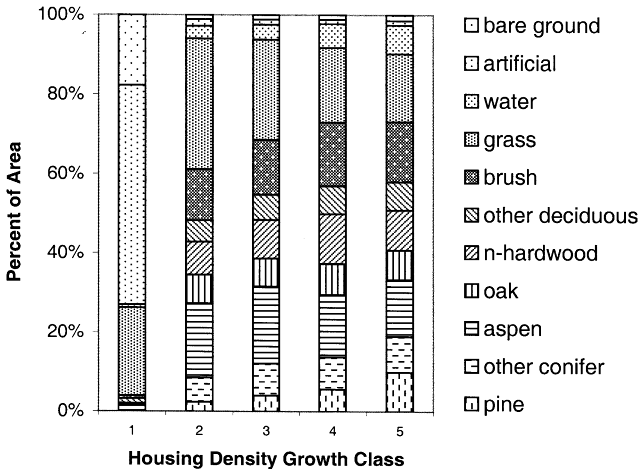

Figure 5. The relative abundance of different land cover classes within each of five housing density growth classes. Class 1 represents census block groups with negative growth. The other classes were defined so that they represent equal areas of the Pine Barrens counties (Class 2: 1–2.170; Class 3: 2.171–2.930; Class 4: 2.931–3.924, Class 5: > 3.924).

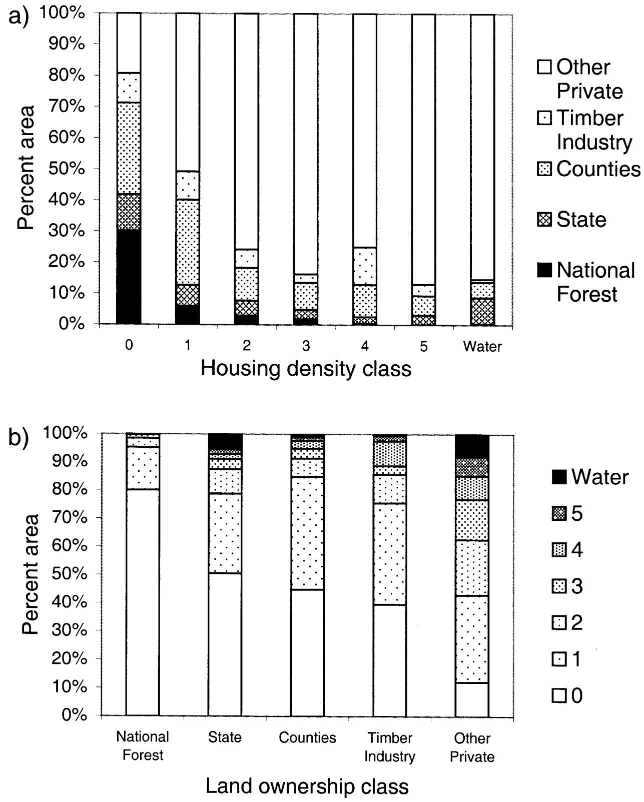

Figure 6. Relationship between 1990 housing density and land ownership data: (a) the relative abundance of different land ownership classes within each 1990 housing density class, and (b) the relative abundance of different 1990 housing density classes within each land ownership class.

Our discussion is based on two assumptions. First, the presettlement landscape provided crucial open habitat that is currently lacking. Providing such habitat is the key *ecological* criterion for management decisions. Second, the creation of open habitat via management, such as clearcutting, is apt to be contentious among residents, particularly neighboring small-scale landowners. A greater number of landowners in a given area will result in a need to involve more people in decision making processes in order to achieve consensus concerning forest management practices, such as clearcutting or prescribed burning. In the absence of detailed spatial data on landownership and landowner attitude, housing density is the key *sociological* criterion when discussing landscape scale management. The validity of these assumptions is discussed below.

Housing Density and Landscape Level Management Options

The northern Pine Barrens exhibited the lowest fire frequency at presettlement times, and the forests contained a mix of red, jack and white pine. Today, this region is mostly forested, but jack pine and deciduous stands have replaced former mixed pine forests (Radeloff et al. 1999). Since the northern Pine Barrens is mostly within the Chequamegon National Forest, the housing density patterns are more homogeneous, and the implications for forest management are more apparent. This area exhibits low housing density and very limited historical housing density growth or potential for such future growth. These factors make landscape level management particularly feasible in this part of the Pine Barrens.

From an ecological perspective, the main management goal may be to re-establish mixed pine forests that contain multiple age cohort red, white, and jack pine. Mixtures of these three species at the stand level are currently rare, and natural regeneration of these forests could be attempted using prescribed surface fires to remove herbaceous and shrub layers. Supplemental planting of red and white pine may be required in areas where no mature trees remain as seed sources.

The central Pine Barrens was historically dominated by jack pine, and experienced extensive crown fires. Jack pine is still the dominant tree species in this area, but landscape patterns have been altered (Radeloff et al. 1999). Previously, large open areas, created by fires, and extensive jack pine stands, formed a shifting mosaic. These historic landscape patterns do not occur currently; smaller clearcuts predominantly shape contemporary landscape patterns. The central Pine Barrens contains large blocks of county forest and private timber industry holdings (Figure 2). Due to these landownership patterns, housing density in the central Pine Barrens is also comparatively low. However, growth rates are higher than in the northern Pine Barrens. Lakes are less abundant than in the southern Pine Barrens, but where they occur, seasonal housing density exhibits local high density clusters. The percentage of housing units that are seasonal are highest in the central Pine Barrens, when compared to the other two regions.

The restoration of large openings previously created by crown fires may be feasible by creating aggregated large clearcuts. This silvicultural tool appears to be a possible solution to reverse the historic trend of decreasing forest opening size (Radeloff et al. 1999). Prescribed burning after harvesting may be beneficial for prairie herbs and associated invertebrates. The areas of high seasonal housing density as well as historic high housing density and projected high housing density growth indicate areas for which landscape level management may prove less feasible in the Central Pine

Barrens. The extensive large-block ownership pattern in the central Pine Barrens both public and private provides a setting where aggregated clearcutting might be more feasible. The Douglas county forest is currently exploring such harvesting schemes (Borgerding et al. 1995). The future of landscape level management in this region may depend on the continuation of large-block land ownership.

During presettlement times, the southern Pine Barrens contained extensive oak and red pine savannas (Radeloff et al. 1998). European settlement removed these ecosystems, and today farming and deciduous forests prevail (Radeloff et al. 1999). The southern Pine Barrens have been particularly affected by housing density growth over the last 50 yr, and this trend is expected to continue (Figure 4). The projections anticipate a large area with housing densities in the highest category (> 16 units/km^2) dominating the southern Pine Barrens by the year 2020. Most of the southern Pine Barrens is in private ownership, making the area particularly prone to development. This area also contains abundant lakes, making the area especially attractive to developers and homeowners.

The lack of red pine/oak savannas is probably the foremost management concern in the southern Pine Barrens from an ecological perspective. Oak savannas are one of the most threatened ecosystems in Wisconsin, and red pine savannas have almost entirely vanished. However, restoration of red pine and oak savannas may only be feasible in relatively small restoration areas. Savanna restoration requires prescribed burning and potentially also planting red pine to reestablish seed sources in the landscape. Prescribed burning is often contentious because of the smoke and the danger that fires may burn out of control and threaten homes (Winter and Fried 2000). Also, some residents may prefer closed forest in the vicinity of their homes (Sullivan 1994). The relatively high housing density across the southern Pine Barrens, the strong growth rates, and the abundance of seasonal homes may make landscape level management objectives especially challenging in this part of the region (Carlsson et al. 1998). Correspondingly, development along the shore is also seen as the highest risk for the ecosystem of the St. Croix National Scenic Riverway (Wenger et al. 2000), which marks the border between Minnesota and Wisconsin in the southern Pine Barrens. The only area within the southern Pine Barrens where housing unit growth does not follow the general pattern is the teardrop shaped southernmost portion of the Pine Barrens. Our projections do not indicate a large increase in housing units, and a significant proportion of this area is owned by state and county government. These low density areas may present an opportunity as red pine and oak savanna restoration sites.

The Pine Barrens represent a fairly unique case, where landscape change due to European settlement over the last 150 yr resulted in *increasing* forest cover. Whereas in many other areas, forest habitat losses have to be mediated, wildlife managers in the Pine Barrens aim to maintain and/or restore large patches of open habitat. Large, aggregated clearcuts may present a viable method to create open habitat in managed forests without preventing timber production. However, the key issue is that openings need to be extensive in size to resemble fire patches. The projected high housing densities across the Pine Barrens may limit the opportunities to create extensive clearcuts in several ways.

First, housing units themselves present physical limitations to extensive clearcuts. For instance, even spacing of housing units at a density of four housing units/km^2 corresponds to 500 m distance between housing units and a maximum clearcut size of 25 ha. In reality, housing units are rarely evenly spaced, and the maximum clearcut size depends on the level of clustering among housing units. Our analysis clearly indicated high density clustering along lakeshores. Similar preferences for building locations have been reported in other areas (Luttick 2000). Detailed spatial information on the location of individual housing units is not available, thereby precluding the calculation of a critical threshold of housing unit density above which landscape level management in the Pine Barrens would no longer be possible.

Second, housing development is often accompanied by fragmentation of land ownership. Small parcel sizes necessitate building consensus among many owners to support clearcuts, as well as increased coordination when timing harvesting operations. Furthermore, housing development in Burnett County in the southern Pine Barrens occurs increasingly at the boundaries of public land holdings. This makes it increasingly difficult for county foresters to acquire land to consolidate their holdings spatially (M. Luedeke, WDNR, 1999, personal communication). These trends in land ownership patterns make landscape level management not impossible to achieve, but pose logistical challenges (Stevens et al. 1999).

Third, home owners may object to extensive clearcuts for esthetic reasons and/or out of environmental concerns. Clearcutting is widely regarded as an environmental menace among the public, especially when clearcuts are large (Kangas and Niemeläinen 1996). As noted, the Pine Barrens present a special case, where clearcuts may be desirable for ecological reasons. Furthermore, many of the common detrimental effects of clearcuts, such as soil erosion, do not occur in the Pine Barrens, because of the lack of topography and surface runoff on the sandy soils. However, residents in the Pine Barrens do not view extensive clearcuts favorably (S. Gilchrist, WDNR, personal communication). An increase in the number of housing units may result in growing public pressure to limit clearcuts. Surveys are necessary to examine the attitudes of home owners to clearcuts in more detail.

Seasonal housing concentration areas present special challenges to landscape level management in the Pine Barrens. Seasonal housing is often more spatially dispersed, presumably because of the desire to live "in the woods." The owners of seasonal homes are more likely to have an urban background and may be less familiar with natural resource extraction than people whose primary residence is in the Pine Barrens, especially during their working years. The response to clearcuts may be quite different among these different types of residents. Surveys are necessary to examine differences in attitude between seasonal and residential home owners. In addition, some of the seasonal housing residents will retire in the Pine Barrens in the future, thus converting seasonal homes into permanent residences. Public involvement in management decisions requires targeting seasonal housing owners as a unique group of stakeholders.

Assumptions and Possible Effects on Results

Our analysis of 1990 housing density and of seasonal housing concentration areas did not necessitate making any assumptions. In contrast, the adjustment of the historic housing densities and the future projections required making several assumptions—these should be kept in mind when interpreting our results.

First, census block groups are the lowest level of geography permitting an analysis of housing unit change. A comparison of the 1990 housing density at the census *block* level (Figure 3) with the census *block group* level (Figure 5) reveals that much of the heterogeneity in the spatial pattern of housing density captured at the finer resolution (i.e., census block) is lost at the census block group level. Medium housing densities at the census block group level may be the result of a single settlement surrounded by areas with no or few housing units. The analysis at the census block group level may have missed or underrepresented the degree of spatial heterogeneity.

Second, our method of adjusting past housing densities for units missing from the 1990 data adds a fixed percentage of housing units to each block group based on the proportion of the housing units in the county located in that block group. This means that block groups that declined or grew very little during the next decade received the same proportional adjustment as block groups that increased significantly. As a result, it is possible to show more housing units at time $t - 1$ than at time t. This might result in an upward bias in housing unit growth in areas with low housing density in earlier census years, especially1940. Those areas may have been more prone to housing demolition resulting in a disproportionally high number of 1940 housing units not accounted for by the 1990 census. The strong increase of housing units throughout our study period limits this problem, but it may be more important when applying our method elsewhere.

Third, our future housing density projections assumed that the average growth rate over the last 50 yr will also apply to the next 30 yr. This is most likely not the case but is a reasonable assumption for projection purposes. The projection method is very simple, fitting into the category of mathematical methods for subnational population projections. It is desirable in this application because it relies on minimal assumptions and does not require additional information such as trends in fertility, mortality, and internal migration (Shryock et al. 1976). The assumption of the continuation of historic growth trends is generally viewed as acceptable. Although the method yields housing unit projections that would be considered inaccurate in many contexts, they are sufficient for relating housing unit density to the types of forestry management applications addressed in this research. Basing projections on a mathematical curve can result in unreasonably large figures for local areas that upon aggregation surpass independently derived projections for the parent region. Since the maximum housing density category that we examine is 16 units per square mile or greater, areas with unreasonably high projected densities do not affect our analysis. However, the projections should only be used as densities with a reasonably low maximum value and should not be used to determine the future actual number of housing units in a block group, municipality, or other more aggregated level of geography.

Housing density growth is affected by many socioeconomic factors, none of which are incorporated in our analysis due to our utilization of a simple mathematical projection method. At the block group level, the rate of housing growth will level off as the area approaches some maximum desired density, or more likely in rural areas once the most attractive areas are developed. The overall economic conditions in the region will affect how much new development will occur and local governments may foster or limit future development. Our extrapolated future housing densities, therefore, should not be interpreted as exact predictions but rather illustrative projected trajectories of possible future growth. What the projections do provide is crucial information to help identify constraints on landscape level management options.

Conclusions

This study presented an approach to integrate landscape ecology, and the analysis of presettlement vegetation and natural disturbance patterns with the analysis of past, current, and future housing density to derive landscape level management recommendations for the northwest Wisconsin Pine Barrens. One current trend in forest management is to attempt management at broader scales. A wealth of landscape ecology studies suggest a need for broad scale management and give forest management recommendations. Unfortunately, most of these management recommendation are presented without taking current and potential future settlement patterns into consideration. We suggest that landscape scale management recommendations should be based on both *ecological* and *sociological* data.

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