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Explaining Human Settlement Patterns in a Recreational Lake District: Vilas County, Wisconsin, USA

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ABSTRACT / Lakeshore development in Vilas County, northern Wisconsin (USA) is heterogeneous, ranging from lakes that are surrounded by homes and commercial establishments to lakes that have no buildings on their shorelines. Development in this recreational area has increased, and since the 1960s over half of new homes have been built on the lakeshore. We examined building density around lakes in relationship to 11 variables, including in-lake, shoreline, and social characteristics. Buildings in many parts of northern Wisconsin tend to be concentrated around shorelines; in Vilas County 61% of all medium-sized buildings (our proxy for residential development) on private land were ≤100 m of a lake. The probability of development on a lake was largely related to lake surface area, with larger, more accessible lakes showing a higher probability of development. Building density along shorelines varied with travel cost, lake surface area, presence of wetlands, and extent of public land ownership. Building density was greater on larger, more accessible lakes that were surrounded by forest (as opposed to wetlands) and public lands. Gaining a more precise understanding of human settlement patterns can help direct planning and resource protection efforts to lakes most likely to experience future development.

Understanding the causes, consequences, and dynamics of human land-use patterns is a critical goal for environmental science and management (Lee and others 1992, Meyer 1995, Wear and others 1996, Duerksen and others 1997, Heasley and Guries 1998, Turner and others 1998, Wear and Bolstad 1998, Dale and others 2000). Land cover worldwide is principally altered by direct human use—through agriculture, grazing, resource extraction, and settlement (Meyer and Turner 1992, Meyer 1995, Dale and others 2000). Human settlement patterns profoundly alter the land surface (Douglas 1994), yet our understanding of the relationships between ecological systems and settlement patterns is incomplete. In the United States, land values in many rural areas have shifted away from agricultural and extractive uses toward residential development (Turner and others 1996, Duerksen and others 1997). In this study, we evaluated the human settlement patterns in a rural recreational lake district in the Upper Midwest, USA, and the factors that explain these patterns.

Lakes, streams, and rivers act as integrators and centers of organization within the landscape, touching nearly all aspects of the natural environment and human culture (Naiman and others 1995, Naiman 1996). Considerable research has addressed the consequences of land use for aquatic ecosystems (Osborne and Wiley 1988, Detenbeck and others 1993, Hunsaker and Levine 1995, Johnson and others 1997, Wang and others 1997, Carpenter and others 1998, Wear and others 1998, Schindler 1999). Aquatic systems, however, also influence landscape patterns (Voss and Fuguitt 1979, Naiman 1996, Naiman and Turner 2000, Radeloff and others 2000, Riera and others 2001), but this influence has received less attention. For example, water quality

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affects property values (Michael and others 1996), attitudes of lakeshore homeowners, and recreational activities (Smith and Mulamoottil 1979). In a study of Wisconsin lakes, perceived water quality was found to include three major components: water clarity, recreational quality, and quality of fishing (Lillie and Mason 1983). A study in Michigan (Tombaugh 1970) probed the factors that influenced vacation home locations, but concentrated exclusively on socioeconomic characteristics of property owners. Previous studies have not, therefore, quantitatively measured the specific characteristics of lakes that attract people.

Northern Wisconsin's lakes and rivers have a long history of human use. Native American tribes have occupied the area for at least 10,000 years. From the beginning, they relied on the region's lakes and rivers for fishing, hunting, and transportation (Vogeler 1986). European explorers were also attracted to the area's aquatic resources. They recognized the lakes' and rivers' potential for fishing, hunting, and transportation, just as later immigrants and settlers saw the potential for the timber and tourism industries. Today, it is obvious to any casual observer that people in northern Wisconsin prefer to settle around lakes, but it is not clear what specific characteristics of lakes make them differentially attractive for human settlement. Lakeshore development is heterogeneous, with some lakes densely developed and others entirely undeveloped. The rate of development has increased since the 1960s, and the average number of buildings on privately owned shorelands has more than doubled in the past 30 years. If the current rate of building persists, all undeveloped lakes not in public ownership could be developed within the next 20 years (Wisconsin Department of Natural Resources 1996). Shoreline development threatens many plants and animals, both terrestrial and aquatic (Meyer and others 1997). Development also has the potential to harm the tourist industry by undermining the sense of solitude that draws many visitors to northern Wisconsin. Understanding the factors that make a lake more or less likely to be developed may be useful to land planners and managers, working in similar environments, to allocate limited resources effectively.

In this study, we examined how lakes in northern Wisconsin have shaped human settlement patterns by relating lake and landscape characteristics to lakeshore development and building density in Vilas County, Wisconsin. We addressed three questions: (1) Where do people settle relative to the lakeshore? (2) Are there qualitative differences between developed and undeveloped lakes? (3) What factors explain the variability in lakeshore development and building density among lakes? A variety of factors interact to determine the spatial arrangement of lakeshore development. We focused on in-lake characteristics, shoreline characteristics, lake size, and social characteristics. In-lake characteristics included color, turbidity, alkalinity, and chlorophyll. Shoreline characteristics included the relative proportion of land in wetland, forest, and grass cover within a 100-m buffer. Lake size was measured by surface area and perimeter. Finally, the social characteristics included a measure of public land ownership and a measure of accessibility (estimated travel cost). We hypothesized that alkalinity, surface area, lake perimeter, percent of land in forest, percent of land in grass, and the percent of land in public ownership would be positively related to development and building density. We further hypothesized that water color, turbidity, chlorophyll concentration, travel cost to lake, and the percent of land in wetland would be negatively related to development and building density.

Study Site

Our study focused on Vilas County, Wisconsin, which encompasses a 2636-km^2 area along the state's boundary with Michigan. Vilas County contains >1300 lakes, which cover 16% of the county's area (Figure 1). Lakes range in size from 0.1 to >1500 ha, in depth from 1 to 33 m, and in fertility from oligotrophic to eutrophic. Other representative limnological conditions include: rainwater-dominated, groundwater-dominated, and drainage lakes; dystrophic lakes; winterkill lakes, temporary and permanent forest ponds, and reservoirs (Wisconsin Department of Natural Resources 1995).

Part of the northwoods region (Vogeler 1986), Vilas County's history is intimately tied to its forests and lakes. This landscape, however, has changed dramatically since European settlement. Prior to European settlement, much of the northern forest was a hardwood–conifer mix of eastern hemlock (*Tsuga canadensis*), birch (*Betula* spp.), and maple (*Acer* spp.) with pines (*Pinus* spp.) occurring on the sandy glacial-outwash plains. Timber extraction began in the mid-1800s. The timber industry depended on rivers and lakes to move its product from forest to processor. The reliance on water meant that softwoods, which floated, were cut and hardwoods were left standing. The construction of the railroads, during the 1880s, brought a new era of logging as both types of wood could now be easily transported and previously remote tracts became accessible. By 1900, most of the forest had been cut, and timber production was rapidly declining due to resource exhaustion (Bawden 1997).

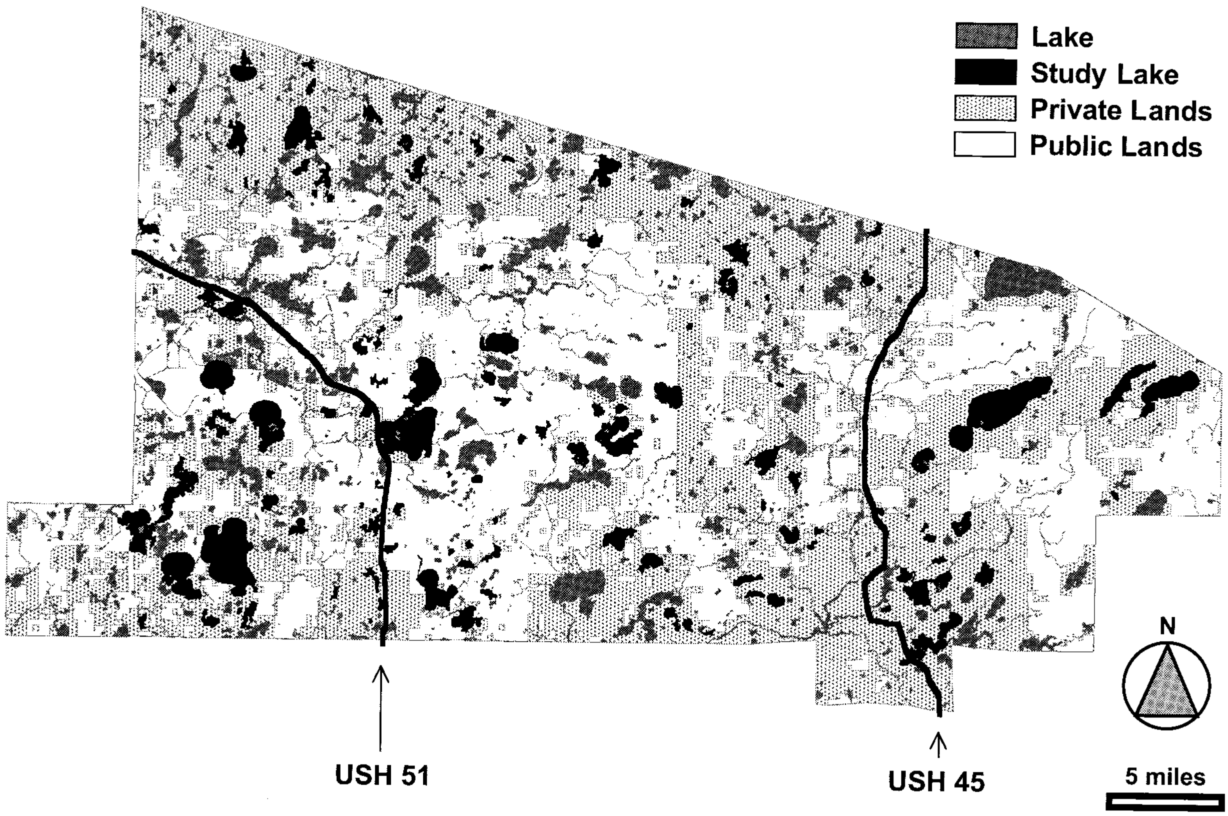

Figure 1. 1990 map of the Vilas County study area. Study lakes are in black and other lakes are in gray. Private lands are indicated with hatching; remaining lands are in public ownership.

Assuming that the "plow would follow the axe," promoters of northern Wisconsin sought to turn the area into a farming region, but poor soils and short growing seasons confounded farmers' attempts at agriculture. After a long struggle and the agricultural depression of the 1920s, reforestation supplanted farming (Carstensen 1958). Tourism developed alongside reforestation, beginning with wealthy urban vacationers in the 1920s, and evolving to include large numbers of recreational homeowners and retirees (Gough 1997, Voss and Fuguitt 1979). Gradually, a new version of the northwoods emerged with jackpine (*Pinus banksiana*), birch (*Betula* spp.), and aspen (*Populus tremuloides*) dominating the forest landscape. While the timber industry continues to operate in northern Wisconsin, recreation and tourism have become increasingly important to the local economy (Nesbit 1973).

Currently, Vilas County is experiencing population growth, and land values are higher than at any time in its history (Figure 2). The increased focus on tourism and recreation has been accompanied by an increase in the number of homes. Zoning records show that an average of 184 new homes per year were built between 1985 and 1989 in Vilas County. This average nearly doubled to 342 new homes per year between 1990 and 1995 (Anderson 1996). Much of this new development has occurred around lakes, with over half of the new homes built in recent years having shoreline frontage (unpublished data).

Methods

Building Density

We used shoreline building density on private land as a proxy for human settlement. Hydrography and building data layers, used in our geographic information system (GIS), were acquired from the Vilas County Land Information Office. These coverages (spatial data sets) are based on a county-wide black-and-white aerial survey conducted in 1996, at a scale of 1:31,680. A land ownership coverage was acquired from the Wisconsin Department of Natural Resources. This coverage identifies public versus private land ownership at the scale of Public Land Survey System (PLSS) quarter-sections. Approximately 53% of Vilas County land is privately owned.

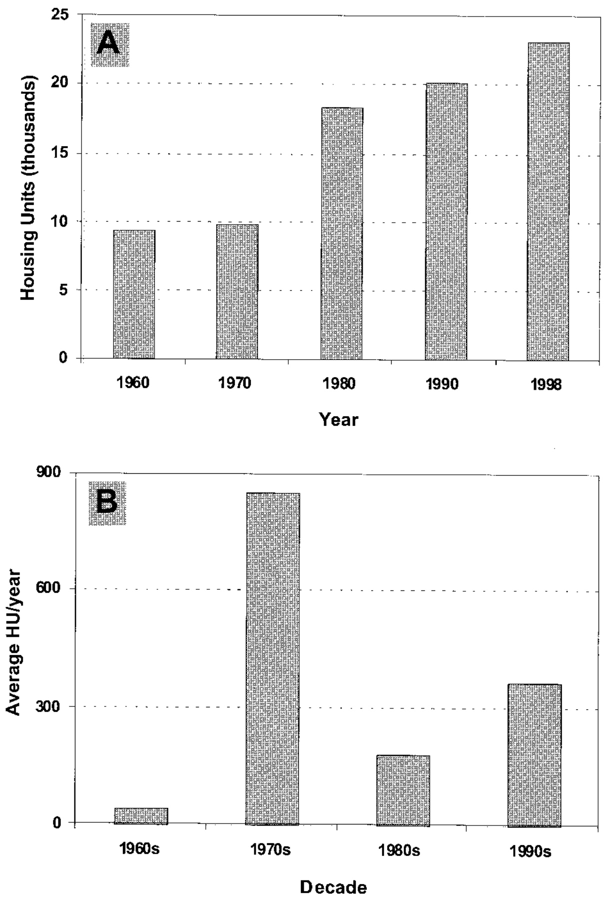

Figure 2. Housing units (HU) in Vilas County: (**A**) total housing units in Vilas County in 1960, 1970, 1980, 1990, and 1998. (**B**) number of new housing units constructed per year during each decade.

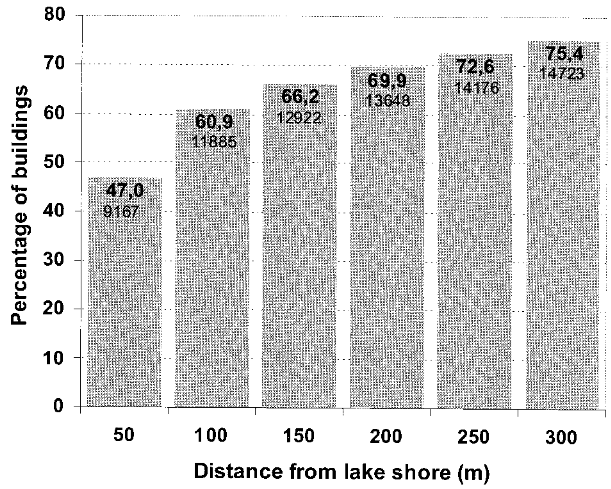

Figure 3. Cumulative distribution of medium size buildings (1000–3000 ft^2) on private land in Vilas County relative to distance from the shoreline of waterbodies with a perimeter-to-area ratio lower than 0.01 (equivalent to lakes >8 ha in surface area). For each bar, the percent (bold) and number of buildings are given. Buildings on private land numbered 30,951, of which medium-sized buildings numbered 19,570. Another 939 buildings occurred on public land.

Housing densities can be derived from census data (Radeloff and others 2000). Such data, however, do not lend themselves to an analysis of housing specifically along lakeshores. Census blocks, the smallest geographic unit measured by the census, are polygons that vary widely in shape and size, especially in rural areas. We therefore chose to use the county building coverage file, which permits exact analysis of building density at various distances from the lakeshore. One problem with this coverage, however, is that, unlike census data, it does not provide information on housing units, per se, but on buildings of all kinds. Fortunately, it does categorize buildings by size of "footprint": small (0–1000 ft^2), medium (1000–3000 ft^2), and large (>3000 ft^2). We identified a total of 31,890 buildings in the Vilas County building coverage. A comparison of this number with a count of 20,225 housing units from the 1990 Census suggests that ca. 62% of the buildings identified in the building coverage are units intended for occupancy—either as seasonal residences or year-round housing (US Bureau of the Census 1991). Of these buildings, 10,408 were coded as small, 20,196 as medium, and 1286 as large. We restricted our analysis to only medium-sized buildings, as this group had the highest zero-order correlation (0.89) between housing units from the 1990 Census and buildings from the County coverage when both were measured at the census block level of geography.

In the exploratory part of our data analysis, we examined the relationship between building counts and distance from shoreline for a series of six concentric buffers around lakes. Each buffer was 50 m wide, thus the sixth buffer extended to 300 m from the shoreline. Since ca. 61% of the county's medium-sized buildings on private land were within the first 100 m of lake shoreline (Figure 3), subsequent analyses were confined to the land area within 100 m of a lakeshore. A 100-m buffer was created around each of 772 lakes using a GIS. We calculated building density by dividing the number of medium-sized buildings on private land within the buffer by the area of private land within the buffer.

We included in our analysis all the lakes in Vilas County that were completely within the county boundaries. To avoid including large streams, reservoirs, and flowages in our study, waterbodies with a perimeter-to-area ratio >0.01 (measured in feet) were eliminated.

Table 1. Descriptive statistics for dependent variable and independent variables[a]

Variable	Units	*N*	Minimum	Maximum	Median	Mean	Standard deviation
Building density within 100 m for medium-sized buildings	buildings/ha	627	0	2.89	0.14	0.42	0.55
Color	PCU	137	0	138	15	26.49	28.9
Turbidity	NTU	127	0	9.5	1.02	1.57	1.57
Alkalinity	m/liter	140	−11.2	1181	207.45	336.02	320.6
Chlorophyll	mg/liter	124	0.7	63.2	5.3	8.21	9.02
Surface area	ha	627	1.11	1591.31	11.39	51.92	130.06
Lake perimeter	m	627	383.55	31698.6	1679.73	3359.92	4300.58
Land cover in wetland	%	627	0	1	0.2	0.29	0.3
Land cover in forest	%	627	0	1	0.71	0.64	0.3
Land cover in grass	%	627	0	0.42	0	0.01	0.04
Public land in 100-m buffer	%	627	0	98	5	20.1	28.4
Travel cost	hours	393	0	1.17	0.52	0.53	0.27

[a]Variable name in bold type indicates that the variable was log-10 transformed for the analyses.

This resulted in a set of 772 lakes with a minimum area of about 8 ha. All analyses were conducted only for private lands, as building is not permitted on most public lands. Of the 772 lakes selected for our study, 627 had private land within the 100-m buffer. Of these, 413 lakes had medium-sized buildings on private land, and 214 had no buildings. The latter we considered "undeveloped."

Independent Variables

The first group of independent variables—color, turbidity, alkalinity, and chlorophyll (Table 1)—are measures of in-lake characteristics. Data for these variables came from a regional lake survey conducted during 1979–1982 of 856 bodies of water in the Upper Midwest (Glass and Sorenson 1994). Data for these four variables together were available for only 113 lakes.

Many factors affect perceived lake color, including concentrations of dissolved and suspended materials, water depth, weather and light conditions, and the angle of observation. Water color depends primarily, however, on the amount of dissolved substances present in the water. The brown color seen in some Wisconsin lakes is usually a result of humic materials that contribute various concentrations of organic acids (Lillie and Mason 1983, Gergel and others 1999). Turbidity measures the suspended particles in the water and affects the water's transparency. A study conducted in Wisconsin indicated that people associate dark, murky water with pollution (David 1971). Smith and Mulamootil (1979) found in a survey of lakeshore homeowners that "clean water" was regarded as "very important" and was ranked among the top three most important amenities for a lakeshore home. We, therefore, posited that both color and turbidity would be negatively related to shoreline development and building density because people generally prefer clear, blue lakes to dark, cloudy lakes.

Alkalinity, reported as milligrams per liter $CaCO_3$ equivalents, is a measure of a lake's buffering capacity. The alkalinity measurement is primarily dependent on the levels of bicarbonate, carbonate, and hydroxide ions present in the water. Although humans would not directly perceive a lake's alkalinity, except in the extremes, it is related to a variety of lake properties including productivity and habitat suitability for most crayfish and fish species. A survey in northern Wisconsin revealed that fishing is the dominant outdoor activity of lakeshore property owners (Klessig 1973). Based on the popularity of fishing, we hypothesized that alkalinity would be positively correlated with shoreline development and building density.

The concentration of chlorophyll in a lake is directly related to the extent of the lake's phytoplankton (algal) biomass. Chlorophyll, therefore, is related to a lake's productivity and fish species richness. Lakes extremely rich in chlorophyll appear green. David (1971) reported that the most important attributes people associated with water pollution were algae and green scum. We hypothesized, therefore, that while people enjoy fishing opportunities, they generally avoid lakes that are very green. Thus shoreline development and building density would be negatively correlated with lakes rich in chlorophyll.

The second group of independent variables measured lake size. Surface area and perimeter of each lake were computed in Arc/Info GIS. People often prefer larger lakes for their scenic views and recreational opportunities. The majority of lakeshore homeowners in Canada indicated that the "size of the lake" was an important amenity (Smith and Mulamoottil 1979). Furthermore, cottagers living on small lakes tended to have a more negative perception of their lake's ecology than cottagers living on large lakes (Smith and Mulamoottil 1979). Larger lakes also tend to be more accessible, deep, and productive. We hypothesized, therefore, that shoreline development and building density would be positively correlated to both lake size and surface area.

The third group of variables measured characteristics of the shoreline and focused on land cover and vegetation. Within the 100-m buffer around each lake, we recorded the proportion of land covered in forest, wetland, or grass. Land cover data were derived from WISCLAND, a land cover data set for Wisconsin based primarily on 1992 Landsat TM satellite data (Lillesand and others 1998). We hypothesized that the percentage of wetland would be negatively correlated to shoreline development and building density and that the percentage of forest would be positively correlated to shoreline development and building density. We hypothesized that there would be a positive correlation between building density and grass based on the observation that many residential property-owners convert the land cover to grass.

The social variables we used were a measure of the extent of publicly owned land in the buffer and a measure of lake accessibility, which we estimated as travel cost. Lakeshore homeowners in northern Wisconsin regarded "solitude and beauty" as the most important pleasure derived from their lake property (Klessig 1973). "Privacy" was cited as an important reason in the purchase of property by recreational homeowners in two northern Wisconsin counties (Preissing and others 1996). Lakes whose shorelines are at least partially surrounded by public land can never be completely filled in with private development. Having the shoreline partially undeveloped would create a greater sense of privacy and solitude. We posited, therefore, that people would prefer to settle on lakes where some of the land was in public holdings. To understand the relationship between public land and building density on private land, we measured the percentage of land in the 100-m buffer that was in public ownership.

Travel cost was defined as the amount of time it takes to get from the closer of the two major highways in the county (highways 51 or 45; see Figure 1). In the district of Muskogee, Ontario, Canada, a tourist region known for its many lakes, cabins around many small and medium-sized lakes have private roads that lack snow plowing or are so poor that they are impassable in spring or late fall. Others lack roads altogether and thus are only used in the summer. Cabins around the larger lakes have better accessibility in most cases (Smith and Mulamoottil 1979). Based on the observation that similar conditions existed in northern Wisconsin, we hypothesized that building density would be negatively correlated to travel cost because development would first occur along the major roadways, following the path of least resistance. Travel cost was estimated using a road coverage derived from the same aerial surveys used for the hydrography and building coverages. Roads were classified (federal highway, state highway, county highway, town roads, forest roads, private roads, and other roads) and assigned a travel speed based on a presumed maximum speed limit. A number of points were selected around each lake and a travel time to each of the two highways was estimated by dividing the distance along each road type by the travel speed. These points were averaged to arrive at a travel cost for the time to get from each lake to highways 45 and 51. Final travel cost for each lake was the shorter of these two travel times.

Data Analysis

The relationship between building density and distance from lakeshore was examined by generating a frequency distribution of buildings within each of the six 50-m buffers surrounding the study lakes in Vilas County. Figure 3 shows the cumulative distribution of medium-size buildings on private land in Vilas County relative to distance from the shoreline of waterbodies with a perimeter-to-area ratio of <0.01 (roughly equivalent to lakes greater than 8 ha in surface area). For each bar in the cumulative frequency function, the percent and number of buildings are given.

Multiple logistic regression was used to determine which characteristics best distinguished between developed and undeveloped lakes. Lakes with one or more medium-sized buildings on private land within the 100-m buffer were considered developed and assigned a value of 1. Lakes with no buildings on private land were considered undeveloped and assigned a value of 0. Logistic regression was conducted using the set of lakes ($N = 122$) for which all independent variables were available and using the full set of lakes with the in-lake variables excluded ($N = 393$).

In addition, we used stepwise multivariate regression with all 11 independent variables for lakes with buildings on private land to determine which factors best predicted building density. Multivariate regression was conducted using the full set of developed lakes ($N = 104$) for which all independent variables were available and using the full set of developed lakes ($N = 316$) with the in-lake variables excluded.

Table 2. Logistic regression excluding in-lake variables[a]

Parameter	Estimate	Standard error	t ratio	P
Constant	1.094	0.559	1.958	0.050
Travel cost	−3.739	0.649	−5.759	0.000
Surface area	2.758	0.392	7.032	0.000
Wetland	−1.24	0.658	−1.885	0.059
Percent public land	−0.015	0.006	−2.554	0.011
McFadden's $R^2 = 0.359$				

[a]$N = 393$; lakes with buildings: 316; lakes with no buildings: 77.

Results

Building Density Versus Distance from Shoreline

There were 19,570 medium-sized buildings on private land in the county (Figure 3), 11,885 of which were within 100 m of the shoreline. Almost 50% of such buildings were within 50 m of a lake shoreline, and 67% were within 150 m. We chose 100 m as our buffer size for this analysis because it appeared to capture the majority of lakeshore development. Fifty meters was too narrow—many lakeshore homes were set farther back—whereas buffers >100 m included homes that were not built on lakefront property.

Developed Versus Undeveloped Lakes

Logistic regression, using the 122 lakes for which all independent variables were available, revealed that the probability of development was affected by travel cost, alkalinity, and surface area. Travel cost was negatively correlated with the probability of development, whereas alkalinity and surface area were positively correlated. While these results conform to our predictions, they should be interpreted with caution. Travel cost showed the highest significance. The other two variables were only marginally significant. Furthermore, given that only nine lakes fell in the undeveloped category, the dependent variable was highly skewed.

A logistic regression analysis for which the in-lake characteristics were excluded ($N = 393$) allowed us to conduct a more balanced analysis with a larger sample size. The results revealed significant effects of travel cost, surface area, the percent of wetland, and the percent of public land (Table 2). Travel cost, percent wetland, and percent public land were negatively associated with the probability of development, while surface area was positively correlated. Another analysis was conducted to test the explanatory power of two variables—travel cost and surface area, the two most significant effects. The goodness-of-fit changed minimally between the four-variable model (0.36) and the two-variable model (0.33), suggesting that travel cost and surface area explain most of the variability in the probability that a lake is developed.

Variability in Lakeshore Development Among Lakes

Multiple regression using the full set of 11 independent variables ($N = 104$) revealed that building density was influenced by the percent of wetland within the 100-m buffer, lake surface area, travel cost, and lake color. Travel cost and the percent of wetland were negatively correlated with building density. Lake area and color were positively correlated with building density. The model explained 32% of the variability in building density. None of the significant variables were collinear except for a positive correlation between lake color and the percent of wetland (Gergel and others 1999).

In a second multivariate regression, in which the in-lake variables were excluded ($N = 316$), surface area, travel cost, the percent of wetland, and the percent of public land were all significant (Table 3), with building density negatively correlated with travel cost and the percent of wetland and positively with the percent of public land and lake area. The model explained 38% of the variability in building density. Despite slight correlations between surface area and both the percent of wetland and public land, collinearity was not a significant problem based on tolerance values.

Discussion

Our analyses revealed that the probability of a lake being developed was explained largely by lake size (surface area) and accessibility (travel cost); the percent of wetlands and public lands were also significant but did not contribute appreciably to explanatory power. The analyses further revealed that building density was related to travel cost, lake surface area, the percent of wetland, and the percent of public land.

Variation in lakeshore development among lakes was generally not explained by in-lake characteristics, except for color and alkalinity, which were only mar-

Table 3. Multiple regression model excluding in-lake variables[a]

Source	*df*	Sum of squares	Mean square	*F* statistic	*Pr* > *F*
Type I tests					
Travel cost	1	32.7632	32.7632	45.17	<.0001
Surface area	1	80.8143	80.8143	111.43	<.0001
Percent wetland	1	21.4014	21.4014	29.51	<.0001
Percent public land	1	7.1522	7.1522	9.86	0.0018
Model	4	142.1311	35.5328	48.99	<.0001
Error	311	225.5553	0.7253		
C total	315	367.6865			
Type III tests					
Travel cost	1	38.4245	38.4245	52.98	<.0001
Surface area	1	43.4723	43.4723	59.94	<.0001
Percent wetland	1	24.5330	24.533	33.83	<.0001
Percent public land	1	7.1522	7.1522	9.86	0.0018

Parameter estimates

Variable	*df*	Estimate	SE	*t* statistic	*Pr* > *t*	Tolerance
Intercept	1	−0.8581	0.1638	−5.24	<.0001	
Travel cost	1	−1.3836	0.1901	−7.28	<.0001	0.9859
Surface area	1	0.2760	0.0357	7.74	<.0001	0.8641
Percent wetland	1	−1.3766	0.2367	−5.82	<.0001	0.9227
Percent public land	1	0.0057	0.0018	3.14	0.0018	0.9163

[a]$N = 316$; root mean square error = 0.85; adjusted $R^2 = 0.38$.

ginally significant. We expected water quality to be a major factor affecting development, as water clarity is an important recreational and aesthetic attribute of lakes (Lillie and Mason 1983) and may directly affect real estate values of lake-front properties (Michael and others 1996). Counter to our expectations, turbidity and chlorophyll did not influence building density, and color was only marginally significant with a trend opposite to that which we expected. Lake color is strongly related to the amount of nearshore wetlands (Gergel and others 1999), and the negative relationship to percent wetlands would have captured the effect for lakes that were highly colored. Lakes in northern Wisconsin and Vilas County generally exhibit low alkalinity. Alkalinity's lack of variability may explain why it was only marginally significant in the logistic regression.

There are several explanations for the lack of explanatory power of in-lake characteristics in our analysis. First, the lakes in northern Wisconsin are generally clean (Overton and others 1986), especially when compared with some of the lakes in the southern half of the state. Thus, the public may perceive water quality in northern Wisconsin's lakes as relatively homogenous and relatively high. Differences that exist may not be easily detected (Lillie and Mason 1983) or may include factors, such as the presence of desirable sport fish, that were not explicitly included in this analysis. Secondly, our measures of water quality may be related to another variable in our analysis, such as lake size, which may obscure their significance. Third, it may be that other factors, such as availability or the cost of land, simply outweigh the relatively subtle differences among lakes when people make decisions about where to purchase or build.

In terms of the influence of out-of-lake characteristics, we found that building density was positively related to the percent of forest and negatively to the percent of wetland. It is important to note that wetland and forest are inversely related and that the percentage of wetland is inversely related to lake size. We also found that building density was positively correlated to lake size. Larger lakes may afford more recreational opportunities and scenic views, and they tend to be easily accessible, deep, and productive. Building density was negatively related to travel cost, suggesting that development may have first occurred along the major roadways, following the path of least resistance.

Finally, as the percentage of publicly owned land increased, building density also increased. Having part of the shoreline surrounded by public land would ensure that some of the lakeshore would be maintained in a natural state, which we believed was deemed desirable by homeowners.

This study has several limitations. Human settlement patterns reflect the outcome of simultaneous and interacting human processes, which are often difficult to tease apart (Wear and Bolstad, 1998). The results are limited to a single snapshot in time and therefore identify correlative rather than causal relationships. The single-point-in-time approach also assumes that the relationship between independent and dependent variables has not changed over time. Many of the homes included in our analysis have been in place for decades. When these older homes were built, conditions in and around the lake were different from current conditions. Thus, a homeowner may have purchased a home or parcel of property when a lake was entirely undeveloped, or when the nearest highway was a good distance away. Furthermore, the current biological and chemical composition of a lake may have been impacted by the process of development; therefore, conditions today may reflect the results of past lakeshore settlement patterns. However, comparison of limnological data obtained by Birge and Juday in the 1930s for lakes in Vilas County with recent data revealed very modest changes in lake chemistry (Eilers and others 1989, Riera and others 2001). The magnitude of change is sufficiently small that lake users would be unlikely to perceive them.

Our analysis did not distinguish among different classes of private land ownership, yet all private lands may not be equally available for development. For example, some private lands may be held by timber companies or other owners who are unwilling to subdivide. Zoning regulations may also restrict some types of development, and variation in property prices among lakes may influence land acquisition decisions. Finally, the analysis was restricted to variables that were widely available. Clearly, other factors not included in this study likely influence the decision to build a lakeshore home, for we explained only a modest percentage of the variance. The location of one's friends, for example, may be a powerful pull to a certain lake, as well as the distance to the local school for families with young children (Preissing and others 1996, Klessig 1973). Many of these factors, however, require different data and would be best addressed through surveys of lakeshore homeowners that inquire into the decisions relating to the location of their home. Despite these limitations, the relatively large number of lakes used in this analysis provides relatively robust results, and the findings fill a gap in the literature relating to the nature of human settlement patterns in a lake district.

A unifying hypothesis that links the ecological and social sciences is that humans respond to cues both from the physical environment and from sociocultural contexts (Riebsame and others 1994). Our analyses demonstrate these effects on patterns of human settlement in Vilas County, Wisconsin. This pattern is important because northern Wisconsin is undergoing rapid social and environmental changes as tourism and second-home development become increasingly important factors shaping the rural countryside (Preissing and others 1996). Examining the influences of shoreline development is an important step towards understanding the interactions between Wisconsin's people and Wisconsin's lakes. By identifying some of the factors involved, we have begun to build a conceptual model of the lake landscape and the human settlement patterns. It is becoming increasingly difficult to find undeveloped lakeshores in Vilas County, and our study suggests that future development may proceed more rapidly on lakes that are larger, closer to road access, and with more forest cover than wetland cover.

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