



IMPACTS TO WILDLIFE FROM LOW DENSITY, EXURBAN DEVELOPMENT

Information and Considerations for the Adirondack Park

By Michale Glennon and Heidi Kretser



ADIRONDACK COMMUNITIES & CONSERVATION PROGRAM

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FOREWORD

Impacts to Wildlife from Low Density, Exurban Development: Information and Considerations for the Adirondack Park is designed to provide information for a wide audience on the causes and consequences of low density, rural development. Recently, concern has begun to arise over low density, rural development occurring in some regions of the Adirondack Park. These concerns brought to our attention the need for a summary of what is known about the ecological consequences what is now commonly referred to as exurban development. This paper will attempt to provide a clear definition of exurban development and its applicability to the Adirondack Park, and will provide a summary of information on what's known about the ecological consequences resulting from this type of development pattern.

Although not explicitly addressed in this paper, we also wish to acknowledge and emphasize the importance of understanding the implications of exurban development on the socio-economic conditions of Adirondack communities. We provide a cursory overview of the human aspects related to this type of development. More in-depth review of existing literature and basic research will be necessary to fully understand the societal implications of continued exurban development. As emphasized by current Wildlife Conservation Society projects, combining social and ecological research is critically important for addressing the conservation issues facing the Adirondack Park.

We hope that this paper may provide information to a variety of audiences, from planners to local government leaders to interested citizens who may wish to have a better understanding of the ecological changes that may be expected from some of the development patterns that have raised concern in the Adirondacks.

ABOUT THE AUTHORS

Michale Glennon grew up in Lake Placid, NY and gained an early appreciation for the complexities of the Adirondack Park Land Use and Development Plan through her father Robert Glennon, who served as legal counsel and executive director to the Adirondack Park Agency from 1974 to 1996. Michale graduated from Lake Placid High School in 1991 and received a B.A. in Environmental and Evolutionary Biology from Dartmouth College in 1995. She completed an M.S. (1997) and Ph.D. (2002) in Environmental and Forest Biology at the State University of New York, College of Environmental Science and Forestry in Syracuse. Since 2003, Michale has worked as an Associate Conservation Scientist for the Wildlife Conservation Society's Adirondack Communities and Conservation Program (WCS ACCP).

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EXECUTIVE SUMMARY

This paper is an attempt to provide information for a wide audience on the causes and consequences to wildlife from low density, rural development. Exurban development is defined as development in semi-rural areas outside of urban and suburban zones and is characterized by low density (5-40 acres or more) and large lot size. Exurban development is one of the primary causes of loss of land and habitat, resulting in 10 times the amount of land-use change attributed to urban and suburban development, and growing faster than any other type of residential area in the U.S. The attraction of natural amenities is probably the primary reason for the large influx of migrants to regions of the country that provide wilderness and open space resources. This influx of migrants has resulted in much concern over the resulting exurban development trends occurring in the Rocky Mountain region of the western United States. Current trends in the Adirondack Park point toward similar patterns of development. Though it has been referred to by a different name, numerous authors have provided key information and raised concerns relating to rural sprawl in the Adirondacks.

The effects to wildlife from development consist of varying types and intensities of impacts including: ecosystem fragmentation, edge effects and nest predation, creation of source-sink dynamics, disruption of wildlife dispersal and movement patterns, effects associated with roads, changes in community composition and structure, effects associated with domestic pets, effects associated with recreation in the surrounding area, human-wildlife conflicts, and cumulative impacts. Much of the work on fragmentation and edge effects has been conducted in agricultural landscapes, or landscapes more fragmented than the Adirondacks, and the extent to which conclusions from that work apply to this ecosystem is not fully understood. However, in general, habitat fragmentation results in a breakup of large habitat patches into smaller, isolated patches and can result in increased nest predation, with potentially significant negative effects to nesting birds. Roads have important direct and indirect effects to wildlife through both direct mortality and disruption of movement and dispersal patterns. Amphibians and reptiles are particularly susceptible to the effects of roads and road construction. The presence of humans, their structures, and the shelter and food sources they create for wildlife can lead to altered population dynamics and increased human-wildlife conflicts around local communities. Domestic pets can have significant effects on local populations of small mammals and songbirds. Increased recreation by humans in areas surrounding exurban developments has many potentially negative impacts to wildlife species, especially in heavily used areas with trails.

If there is any overall theme in the observed effects of human development on wildlife, it is that development tends to result in an increase in the representation of generalist, commensal species, and a decrease in representation of specialized and human-sensitive species. Long-term effects of this apparent ecosystem simplification are unknown. Each of these topics is addressed in depth here, along with a specific treatment of studies conducted exclusively in exurban landscapes.

A common misconception of exurban development is that, because most of the matrix remains in the original habitat type, effects to wildlife are minimal. Several studies have provided evidence to the contrary and demonstrated that it cannot be assumed that because most of the land within exurban developments remains undeveloped, it is suitable for all species that would occur there in the absence of houses. Numerous examples of tools and analyses exist that may be helpful in planning for future development in the most ecologically sustainable manner and mitigating some of the negative effects to wildlife from exurban development discussed in this paper. One of the most commonly cited tools for combating the effects of exurban development is clustering. Clustered developments decrease fragmentation and perforation of habitats created by roads and houses, and allow for the remainder of the landscape to be in a condition more suitable for wildlife sensitive to elevated human densities. The potential application of clustered designs in the Adirondacks is an important research need.

Two books by Randall Arendt (1996, 1999) describe “conservation subdivisions” and provide a means by which to arrange density on each potential subdivision as it is being planned so that half (or less) of the buildable land is used by houses and streets, with the remainder in permanent protection and added to an interconnected network of green spaces across the landscape. Other tools, both in the literature and on the internet, are discussed and provide means by which development may be monitored, predicted, and carefully planned. Readers who wish to access the parts of this paper that are probably most applicable and useful for local communities should pay particular attention to sections 3 and 4, where we discuss possible solutions to the problems created by exurban development, and recommendations for the Adirondack Park.

In the concluding section of this document, we provide specific recommendations for the Adirondacks which can be loosely described as (1) recognition of the criticalness of private lands in the Park, (2) monitoring and inventory of key Park resources, (3) and following of identified guidelines to protect wildlife at both local and landscape scales. The American Planning Association provides principles for protecting wildlife and planning

developments with wildlife as a focus. These recommendations are highlighted in the conclusion. We also discuss key research needs for the Adirondacks including:

- Determining an appropriate building effect distance for the Adirondacks and other eastern regions.
- Examining the differences between the effects to wildlife from seasonal and permanent occupancy.
- Identifying regions across the entire Park most vulnerable to future development.
- Implementing a consistent and well-designed monitoring system of socio-economic, cultural, aesthetic, physical and biological resources.
- Evaluating residents' values, attitudes, and perceptions toward wildlife and human-wildlife interactions.
- Understanding residents' expectations for housing placement and landscape qualities.
- Developing methods to allow stakeholders to visualize realistic future development impacts and alternatives.
- Researching potential clustering designs for new developments and their potential impacts to wildlife and ecosystems.

It is hoped that this paper will provide a catalyst for opening the dialogue about low-density development impacts and inspiring research to understand and mitigate negative impacts, with the ultimate goal of improving the Adirondack Park's human and biological communities.

INTRODUCTION

Purpose of this paper

This paper is an attempt to provide information for a wide audience on the causes and consequences of low density, rural development. Recently, concern has begun to arise over low density, rural development occurring in some regions of the Adirondack Park. As development of desirable waterfront properties has reached capacity in many areas, pressure is increasing for large-lot development in backcountry areas (Dunne 1990). Several recent development proposals have raised questions about the long-term cumulative ecological and sociological impacts these developments will have on the character and ecological integrity of the Park. Pressure for development of traditionally open-space lands is increasing and there is a general perception that these developments will be “precedent setting” because of the demand for homes in the woods and the desire for large lots. In combination with the attractiveness of large wilderness lots, the cost of living in some of the more popular towns in the Adirondacks has risen to a point at which local residents can no longer afford to live locally and are forced to relocate to more marginal lands outside of town, further increasing development pressure on open space.

These concerns brought to our attention the need for a summary of what is known about the ecological consequences of low density, rural development, a pattern which is now commonly referred to as exurban development. This paper will make an attempt to provide a clear definition for what exurban development is and its applicability to the Adirondack Park, and will provide a summary of information on what is known about the ecological consequences resulting from this kind of development pattern. It is hoped that this paper may provide information to a variety of audiences, from planners to local government leaders to interested citizens who may wish to have a better understanding of the ecological changes that may be expected from some of the development patterns that have raised concern in the Adirondacks. This paper will provide some very preliminary ideas on how the negative ecological consequences of exurban development may be mitigated in planning for future development. Curran (1990) gives a very thorough treatment of the environmental implications of development and this paper is not meant to supplant information he provided, but rather to expand upon the environmental implications of development specifically as they pertain to effects on wildlife.

What is exurban development?

In 1955, Auguste Spector sky described a new type of commuter living in the metropolitan area of New York City – the exurbanite. He defined exurbanites as generally upper class, working in New York City but living in the outlying areas, often beyond the end of commuter railroads. Exurbanites owned homes in the “exurb,” areas farther away from NYC than the suburbs. Exurbs tend to have more widely spaced and more expensive houses with a variety of designs and features. An exurbanite lives far away from the urban zone yet is still within commuting distance.

In this description, exurbanites will “spiritually...always be urban” (Spectorsky 1955, p7).

Since the first account of exurbanites, the term has morphed into numerous derivatives and been used loosely to describe low-density development at or beyond the rural-urban fringe. *Exurbia* is “the rural residential area beyond the suburbs but within the commuting range of the urban/suburban area [of a city]” (Nelson 1992, p350). The *exurb* is created as people move from the city into the country. The subsequent counter urbanization results in a new urban form – the exurb (Davis and Nelson 1994). *Exurbanization* or *exurban growth* has been described as an extension of suburban development or new type of settlement pattern (Davis and Nelson 1994), as development occurring beyond the limits of incorporated cities and towns (Knight 1999), and as rural development that does not fit traditional urban growth models (Odell and Knight 2001). Unlike suburbia, exurban landscapes are characterized by a matrix that remains in the original ecosystem type (Odell and Knight 2001).

Transformations in the transportation and computer industries have enabled commuting to take on a different meaning. One can commute daily in the traditional sense by way of automobile or train to a central office. Or, one can commute via remote Internet access and only infrequently visit an office. While the exurbanite of the 1950s lived along the dendritic arms of the rail lines within 70 miles of New York City, the exurbanite in the 2000s can live almost anywhere in the world where high speed Internet, phone lines, and satellite connections enable 24-hour commuting. This form of commuting has enabled more and more people to move to a place because of its qualities, not the availability of jobs. This form of commuting has extended the ‘arms’ of exurban growth. The exurbanite of yesterday was connected elsewhere through employment and distance to work was a limiting factor. The exurbanite of today can literally move almost anywhere. As a result, the definition of exurban must be modified to include those areas developing where people still have a connection to an urban center, not just the regions beyond the suburban fringe.



Credit: L. Karasin

An example of exurban development in Montana, USA.

Exurban landscapes are increasingly defined in terms of density. Development at the rural-urban fringe has been defined as a semi-rural area outside of urban and

suburban zones characterized by low density large lots of about 5 to 10 acres (Daniels 1999). Theobald (2004), who works mostly in the western United States, offered the following development classifications based on housing density: urban as more than 1 housing unit per acre, suburban as 1 unit per 1-10 acres, exurban as 1 unit per 10-40 acres, and rural as 1 unit per 41 or more acres. The Ohio Exurban Change Project offered the following lot size characterizations of exurbia: high settlement ≤ 1.65 acres per house, medium-exurban = 1.65-16.5 acres per house, low-emerging exurbia = 16.5-165 acres per house, and very low settlement ≥ 165 acres per house (Clark et al. 2005). Given the diversity of exurban density descriptions and the diversity between the landscapes of the western and eastern United States, for the purposes of this paper we will refer to exurban development as 1 unit per 5-40 acres. The bulk of attention and concern over the trend of exurbanization has occurred in the Rocky Mountain West (Odell and Knight 2001, Maestas et al. 2001), but concern over rural residential development patterns have also been expressed in many parts of the country and world, especially in areas of high amenity values, including Arizona (Germaine et al. 1998), Oklahoma (Boren et al. 1999), the Pacific Northwest (Hammer et al 2004), the Rocky Mountains (Riebsame et al 1994), the Minnesota and Wisconsin lakes region (Malandri 2004, Blahna 1990), small towns of New England (Steel 1999), Australia (Burnley and Murphy 1995), Africa (Nkambwe and Arnberg 1996), French Guiana (Reynaud and Thioulouse 2000), and Finland (Clergeau et al. 2001), to name a few.

What causes exurban development?

The causes of exurban development are also not well studied but lie primarily in sociological and economic factors. With increasing wealth and mobility, private lands in close proximity to protected areas have become attractive lands for second-home development and amenity migration – where people move to rural areas rich in natural resources (Moss 2003; Stewart 2000; Davis and Nelson 1994). Much attention has been paid to the overwhelming influx of in-migrants to the Rocky Mountain region of the western United States. Although there is uncertainty about why people and businesses are attracted to the mountain west, there are numerous potential causes, not the least of which is that recent improvement in electronic communication makes living and working in rural areas easier (Levitt 2002) and working from home a possibility for a much larger segment of the American population. The attraction of natural amenities is probably the primary reason for the large influx of migrants to the Rocky Mountain West, and other regions of the country (Crump 2003) such as the Adirondack Park. Scenery, proximity to wilderness, outdoor recreational opportunities, and wildlife are all valuable amenities in high demand (Johnson and Rasker 1995, Beale and Johnson 1998).

A common corollary of amenity migration and a further cause of exurban development is the increase in housing values in high amenity locations, forcing some current residents to relocate to other areas (Miller 2002). Increased cost of living in popular destination areas can often force local residents to relocate to marginal areas outside of town, further driving the push for rural residential development. A poll conducted by the National Association of Realtors demonstrates a surge in the second-home market (NAR 2005). The survey shows that, for the first time, the purchase of investment homes exceeds the purchase of vacation homes. The second

home market accounts for over one-third of all residential housing sales. The data also indicates that investment-property buyers have a higher household income than vacation-home buyers. In some situations, competition with second home buyers and increasing housing values can force current residents to relocate into other less-expensive areas (Miller 2002), adding pressure to develop marginal lands – furthering the impacts of fragmentation. These trends have the potential to drastically alter an area by creating seasonal communities with small labor forces to serve periodic high demands (Murphy 2001). Additionally, with investment properties becoming more popular, some highly desirable communities may experience periods, even during peak season, with few people living in neighborhoods primarily owned as second-home investment properties (Kretser, unpublished data). This pattern has the long-term potential of transforming a relatively rural landscape with few seasonal homes in select locations to one with numerous homes spaced widely across the landscape in a pattern less dense than suburbia but more dense than traditional rural areas.

Why should we be concerned about exurban development?

Exurban development is one of the primary causes of loss of land and habitat. Exurban development (5-40 acres per house) causes 10 times the amount of land-use change attributed to urban and suburban development in the U.S. (USDA NRI 2003). Exurban areas are growing faster than any other type of residential area in the U.S., resulting in the conversion of rural and open space to low density rural housing (Crump 2003; Pendall 2003). Between 1960 and 1990, low-density development increased from 156 million acres to 333 million acres in the U.S. (Theobald 2001) and nearly 80% of the land used for home construction between 1994 and 1997 in the U.S. was in nonmetropolitan areas with the majority of homes being built on lots at least 4 ha (~10 acres) in size (Heimlich and Anderson 2001). These types of developments increase the influence associated with human residences at both the site scale, through highly dispersed housing, and the landscape scale, through the placement of developments in rural areas (Duerksen et al. 1996).

We should be concerned about exurban development because, in contrast to the ecological consequences of urban and suburban development, the effects of exurban development are not well studied (Maestas et al. 2001). Most of the existing research comes from the western United States, and the degree to which the conclusions from that research are applicable to the northeast is unknown. Current research suggests that large-scale fragmentation resulting from exurban development may decrease biotic integrity, alter species behavior and composition, and increase human-wildlife conflict (Odell and Knight 2001, Glennon 2002, Beckmann and Berger 2003a, Baron 2004, Glennon and Porter 2005). Apart from the suspected direct impacts to wildlife caused by loss and fragmentation of habitat, exurban development patterns may also be more likely to result in human-wildlife conflict (Baron 2004, Wolch et al. 1995), which has implications beyond the incidents themselves. A recent survey by the International Association of Fish and Wildlife Agencies indicates a decline in support for conservation among the general public as development and habitat loss bring humans and wildlife into conflict more frequently (IAFWA 2004). The success of biodiversity conservation depends on broad-based public support (Miller and Hobbs 2002) and, because most threatened species occur on private lands, a decrease in

overall support for conservation does not bode well for long term biodiversity preservation.

While not the focus of this paper, we should also be concerned about exurban development given the changes this type of development can bring to local communities. As mentioned earlier, the second home and investment market driving exurban development may squeeze local residents out of the housing market. The implications of this are many - difficulty finding affordable housing, declines in the number of full-time residents, declines in the number of students attending schools, declines in social capital for community organizations and volunteer groups, and potential conflict between newcomers and longtimers as well as seasonal and permanent residents (Clendenning et al. 2005, Besanceney 2005, Halseth 1998, Kretser unpublished data). In addition, exurban development, like suburban development, may increase financial demands on local governments to provide infrastructure such as sewer, water, and electric to new building developments. To offset these costs, residents may experience higher property taxes and local communities may assume high levels of debt (Pendall 1999).

Is exurban development occurring in the Adirondacks?

The six million acre Adirondack Park in Northern New York State is often regarded as a model for conservation planning because it embodies a mosaic of constitutionally protected public lands and private lands with strict zoning regulations within its boundaries (McMartin 1999, Terrie 1997). A study released in 2003 by The Brookings Institution demonstrated that between 1982 and 1997, although the New



Averyville Road in Lake Placid,
from the air (c. 1980).

York State population was declining, the population became more spread across the landscape (Pendall 2003). However, in Northern New York, the population increased almost 9% and urbanized (in this instance loosely defined by the U.S. Department of Agriculture as the built environment) lands increased by 40%. These findings coincide with the trend of exurban development occurring in many areas in close proximity to natural amenities such as the Greater Yellowstone Ecosystem and areas in and around the Rocky Mountains (Hansen et al. 2002, Theobald 2000).

Though the bulk of the attention being paid to exurban development is occurring in the West, current trends in the Adirondacks point toward similar patterns of development in this landscape. Though it has been referred to by a different name, Curran (1990), Dunne (1990), Miller (1990), and Bauer (2001) have all provided key information and raised concerns relating to rural sprawl in the Adirondacks. Bauer (2001) analyzed data from 1990-1999 to examine rates of

development in the Adirondack Park and found that the Park was gaining approximately 820-850 new structures per year. Although evidence suggests that development was heaviest along roadsides and lakeshores in rural use, moderate intensity, low intensity, and hamlet areas, data do not show what size lots are being developed. At the landscape scale, measuring net density as acres per house unit by census block for the 13 county northern New York region indicates the extent of current exurban development surrounding the Park and in key areas of the Park interior (Appendix A). These results exclude protected lands in the area calculation, providing a net density rather than a gross density measurement. At the Park scale, over 40 percent of the Park is zoned for development of 1 single dwelling per 8.5 to 42.7 acres (Adirondack Park Agency Act 1973), similar to existing definitions of exurban growth (Theobald 2001; Appendix B).

In an examination of subdivision trends, Miller (1990) pointed out that the average lot size for subdivisions in the Adirondacks increased from 1.8 acres in the 1970s to 4.9 acres in the 1980s. For the period from 1969-1989, subdivisions in rural use and resource management made up 25.5% of all subdivisions filed. Among all subdivisions filed during this time period, those of 5-10 acres made up 8.6% of lots, and subdivisions of 10-40 acres made up 3.2% of lots. Miller's (1990) study was part of the Governor's Commission report on the Adirondacks in the 21st Century (Adirondack Park Agency 1990). The Commission was specifically asked to examine where subdivision was occurring with respect to Park resources and especially in reference to shoreline, road corridor, and backcountry areas. Between 1969 and 1989, 18% of subdivisions were located in the backcountry, 41% along shorelines, and 54% along public road frontage (Miller 1990).

Also part of the Commission reports, Dunne (1990) discussed the economic considerations related to development in the Adirondacks and highlighted a type of subdivision activity that had become prominent in the Adirondacks and northeast at the time of his study, that being the creation of large house lots that are considerably larger than more traditional subdivisions of the past. These characteristics are certainly reflective of exurban development. Dunne (1990) pointed out that there was a growing incidence of these kinds of projects in the 1980s, and while they are not new to the Adirondacks, the extensive use they make of forest and/or agricultural lands make them a source of concern from a state, regional, or national land management viewpoint. Again, these are some of the key concerns being raised by those studying and bringing attention to the notion of exurban development.

Population changes also point toward changes similar to those exhibited by exurban development. The Adirondack Park in 1960 had approximately 5.95 people per square kilometer, by 1986 that number increased to 7.26 per square kilometer (Dunne 1990). More recent data makes it easier to understand how particular areas of the Park may be more vulnerable to population and development pressures. An example is provided by comparing the population changes between interior towns and ring towns. In 1990, the interior towns had populations ranging from 0.39 to 3.86 per square kilometer, whereas the towns surrounding the outside of the park border or ring towns and the Tri-lakes (the 3 largest communities inside the Park: Saranac Lake,

Tupper Lake, and Lake Placid) had 3.86 to 19.31 people per square kilometer. By 2000, the ring towns and the Tri-Lakes region in the central northern part of the Park had 19.31 to 38.61 people per square kilometer (Jenkins and Keal 2004).

In addition to population trends, Dunne (1990) also points out some of the social and economic trends similar to those bringing an influx of migrants and associated exurban development to the Rocky Mountain West (Maestas et al. 2001, Hansen et al. 2002). Personal income growth in New York and surrounding states in the northeast has often surpassed national levels and much of the region's growth has been in the technical, financial, and allied sectors. These factors, together with the widespread urbanization and relatively high income levels found throughout the northeast make the Adirondacks a prime source of leisure and recreation oriented demand (Dunne 1990). Another contributing factor in the Adirondacks has been the growing activity of firms specializing in large lot subdivisions, which fill an apparent market gap between rural landowners wishing to sell acreage and urban residents wishing to buy it for residential/recreational use (Dunne 1990). Evidence from preliminary interviews conducted with realtors, town supervisors, and assessors in the Adirondack Park suggests that this marketing and development trend continues (Kretser, unpublished data).

Further evidence from preliminary interviews with realtors, town supervisors, and assessors suggests the Adirondacks are a popular new home destination for telecommuters and retirees. Since 2000, the decline in stock market values combined with the terrorist attacks of September 11, 2001 have made the northern New York region an even more desirable place to live (Kretser, unpublished data). People are motivated to move to low density lots in high amenity areas for a multitude of reasons including the desire to seek isolation, access to recreation, small town qualities, and scenic beauty (Davis and Nelson 1994, Howe et al. 1997, Knight and Landres 1998, Crump 2003). However, it is unclear specifically who is moving to these areas, what motivates these individuals to move, and what their relationship is with the surrounding wildlife. It is unknown what expectations people who move to these areas have about the natural environment including wildlife and landscape qualities; or how these new residents perceive the responsibility of the local governing bodies to address conservation issues that may arise. Once the new residents live in the area for a certain period of time, it is unknown whether their experiences change their attitudes or perceptions towards land management, conservation, and wildlife. Answers to these questions will be critical as more proposals for large-lot developments in the Adirondacks arise.

The factors discussed here highlight a trend in the Adirondacks of large lot, exurban development for both year-round and seasonal occupancy, and the forces driving the trend are unlikely to decrease in the near future. Harper et al. (1990) pointed out that the forested sections of New York, Vermont, New Hampshire, and Maine are the last major area available to meet the need for peace and solitude for tens of millions of northeastern residents. Extensive development of backcountry areas in the Adirondacks and throughout the Northern Forest will likely result in a significant decline in the qualities of peace and solitude sought by many.

ECOLOGICAL CHANGES AND IMPACTS TO WILDLIFE FROM DEVELOPMENT

Ecosystem fragmentation and associated environmental changes

One of the primary concerns relating to the effects of development on wildlife is that it results in loss and fragmentation of habitat. E.O. Wilson identified habitat destruction as one of the four “mindless horsemen of the environmental apocalypse” and as the primary cause of biodiversity loss in recent time (Wilson 1992). Entire books and countless articles have been written on fragmentation and its effects, and a comprehensive treatment of the topic is beyond the scope of this paper. We will, however, make an attempt to provide a framework for what fragmentation means and to highlight a few important studies that summarize some of the known effects of fragmentation on wildlife populations.

Two papers provide key information related to fragmentation. Saunders et al. (1991) reviewed the biological consequences of ecosystem fragmentation and highlighted many of the associated abiotic factors that are important in impacting wildlife species and populations. Fragmentation is generally defined as the process whereby habitat is reduced from its original extent to a series of smaller patches or fragments. Information from Saunders et al. (1991) relates primarily to extensively fragmented landscapes such as those created by agriculture, and in which remnant patches exist around which most or all of the native vegetation has been removed. The primary effects of this kind of fragmentation are

- (1) an alteration of the microclimate within and surrounding remnants, and
- (2) the isolation of remnants from other patches within the landscape (Saunders et al. 1991).

Changes related to alteration of microclimate include:

- (1) radiation fluxes which change the energy balance of a fragmented landscape and may affect nutrient cycling processes,
- (2) changes in wind regimes, which may affect gas exchange and pollen transfer among plants and also affect breeding success of birds, and
- (3) changes in water flux, which affect rainfall interception by plants and soil moisture levels and may decrease the buffering capacity of the hydrological system.

Factors related to isolation and its potential impacts include:

- (1) time since isolation, which will determine the current makeup of species within a fragment,
- (2) the distance from other fragments, which will also determine species composition depending on colonizing abilities of different species,
- (3) connectivity, which can help mitigate isolation by providing enhanced movement, foraging areas, and refuges, and
- (4) changes to the surrounding landscape which may include removal of native vegetation and increased prevalence of invasive species (Saunders et al. 1991).

While the biotic changes discussed in Saunders et al. (1991) are important in considering the ecological consequences of fragmentation, there is a wide range of

parameters that may define what fragmentation means in any given landscape. McIntyre and Hobbs (1999) attempt to address this issue by providing a framework for conceptualizing human effects on landscapes. The authors point out that human modification of habitat occurs at multiple levels and that the degree to which habitat is modified may be more instructive than a simple distinction of habitat versus nonhabitat, as is characteristic of much of the fragmentation literature. They propose 4 states that describe a continuum of landscape alteration:

- (1) *intact*: with >90% of original habitat remaining, high connectivity, and low modification of remaining habitat,
- (2) *variegated*: with 60-90% of original habitat remaining, generally high connectivity for most species, and low to high degree of modification of remaining habitat,
- (3) *fragmented*: with 10-60% of original habitat remaining, generally low connectivity, and low to high degree of modification of remaining habitat, and
- (4) *relictual*: with <10% of the original habitat remaining, no connectivity, and a generally highly modified matrix (McIntyre and Hobbs 1999).

These terms and parameters are useful in considering potential impacts of fragmentation. The authors also point out that the way different species interact with and perceive different states of landscape alteration is probably more significant than the human perspective on the landscape and suggest that identifying functional groups within taxa such as disturbance tolerators, disturbance dependents, or sensitive species may be more useful (McIntyre and Hobbs 1999).

Much work has been done which demonstrates the effects of fragmentation on wildlife species and published papers pertaining to fragmentation number in the hundreds. Debinski and Holt (2000) attempted to summarize trends found by researchers investigating fragmentation effects and they provide a very good analysis and summary of fragmentation effects based on experimental studies. Unlike descriptive studies, experimental studies allow for the control of important factors such as time since fragmentation occurred, patch size, degree of replication, site initiation, and position on the landscape. From their analysis of 20 experimental fragmentation studies, they found an overall lack of consistency in response to fragmentation and a wide range of species-specific responses. In studies conducted on arthropods, results agreed most closely with theoretical expectations that predict higher species richness on larger fragments as expected from island biogeography theory. In studies conducted on other taxa such as more mobile birds and mammals, early-successional plant species, long-lived species, and generalist predators, results were mixed. Two hypotheses that were frequently supported were (1) that species movement was positively affected by corridors and (2) species richness was positively affected by connectivity. Though their study demonstrates that effects of fragmentation cannot be generalized across taxa, Debinski and Holt (2000) rightly point out the importance of connectivity in fragmented landscapes.

One other study is particularly relevant to this paper, as it attempts to discern effects created by both fragmentation and residential development, and the interaction between the two. Friesen et al. (1995) conducted a study to separate the effects of

residential development from forest size on bird populations in Ontario. They found that richness and abundance of neotropical migrants consistently increased as size of forest increased, and, perhaps more importantly, the number of houses surrounding a forest severely reduced its suitability for neotropical migrants. Diversity and abundance of neotropical migrants consistently decreased as the level of adjacent development increased, irrespective of the size of the forest. This study suggests that external effects can have severe impacts on the ecological value of adjacent forests (Friesen et al. 1995). The authors found that large forests appeared as vulnerable to development as small forests and, therefore, that external effects were not dependent on forest size. Friesen et al. (1995) conclude that keeping forests intact may not be enough to maintain healthy forest bird communities.

In sum, the effects of fragmentation cannot be easily summarized across taxa. As a force on the landscape, however, fragmentation tends to result in a reduction of total available habitat area, a reduction in the size of habitat patches, a reduction in the proximity of habitat patches, and an increase in the amount of edge present in the landscape. Also, although individual species' responses to fragmentation are varied, fragmentation has generally been found to have a negative effect on numbers of species. Andrén (1994) points out that, among the factors associated with fragmentation, only the potential increase in habitat diversity may have a positive effect on species richness.

Edge effects and nest predation

One of the results of fragmentation that has received the most attention, especially with respect to birds, is creation of edge and associated edge effect. Many studies have investigated the effects of edge on nesting success of birds. Several hypotheses have been raised that are relevant to the concern over edge effects on nest success. One relates to the notion that edges are attractive areas for birds to nest because of the increased density of vegetation and therefore cover created along forest edges. Birds may be attracted to edges by these characteristics, but in fact suffer reduced nest success in edges due to increased predation. This phenomenon is often termed an "ecological trap," whereby a particular resource may draw species into an area, where they then suffer reduced fitness in some way. The thought with respect to nest predation is that edges are places in which predators can more easily detect nests, and that forest edges themselves can create natural travel corridors for predators, increasing the likelihood of them coming into contact with bird nests placed along a forest edge. It has also been hypothesized that predators are more abundant in small habitat patches and fragmented landscapes and may be more active and/or abundant in edges (Chalfoun et al. 2002).

Similar to fragmentation, a full discussion of all of the literature relevant to edge and nest success studies is impractical in this context. However, some important studies can be highlighted. Chalfoun et al. (2002) examined the evidence for nest predation and fragmentation by reviewing a large number of studies and conducting a meta-analysis of tested predator effects. The authors tested potential predator effects including increased abundance, activity, or species richness of predators in edges, small patches, or certain landscapes. They found that effects were more apparent:

- (1) in tests conducted at the landscape scale than at the local scale,
- (2) in agricultural landscapes than in primarily forested landscapes,
- (3) in particular biogeographic regions, and
- (4) for avian predators than for mammalian predators (Chalfoun et al. 2002).

Chalfoun et al. (2002) conclude that the response of nest predators to fragmentation is apparently complex, taxon-specific, and context dependent, and that efforts to mitigate negative effects of nest predators may require specificity with respect to predator type and landscape context.

Chalfoun et al. (2002) did not review any studies that occurred in urban or suburban landscapes, and most work on nest predation and edge effects has been conducted in fragmented agricultural landscapes. However, Jokimäki and Huhta (2000) examined nest predation indirectly using artificial nests along an urban gradient from an uninhabited forest to the town center in three towns in Finland. They found that artificial ground nests with Japanese quail eggs were subject to higher predation rates within urban areas than in adjacent forest areas, and that within each town, the nest predation rate was higher in the center of town than in the less urbanized area surrounding the town center. Stray cats, foxes, and other mammalian nest predators, have been demonstrated to reduce the nesting success of ground nesting birds in many towns (Gilbert 1989). Jokimäki and Huhta (2000) found higher rates of predation by mammals at the more rural end of the gradient, while avian predation was more common at the more urbanized end of the gradient, concluding that the importance of mammals in nest predation may therefore be more pronounced in less urbanized areas and in forests.

Paton (1994) points out that most studies of habitat edge have been conducted in Eastern deciduous forests, in small, isolated fragments surrounded by agricultural fields and the studies highlighted above are probably most relevant to the forest/open types of edges created by agriculture, development, and/or forestry. Fewer studies have investigated the effects of internal, rather than external edges created by human developments such as roads, utility right-of-ways, and recreational trails (Miller et al. 1998). Studies by Hickman (1990) and Rich et al. (1994) determined that avian nest predators responded and were attracted to narrow, open corridors typified by internal edges, and suggest that this may result in higher nest predation rates along internal edges and corridors (Miller et al. 1998). Nest predation is the leading mortality source for land birds (Skutch 1985). In addition, nest predation may influence both habitat selection and community structure (Sieving and Willson 1998, Miller and Hobbs 2000). These and other studies suggest that fragmentation by narrow corridors, such as roads and utility rights-of-way, results in edge effects (Miller et al. 1998). Ferris (1979), Kroodsma (1982), Rich et al. (1994), and Hanowski and Niemi (1995) found increased abundance of edge species and decreased abundance of habitat interior species near corridors (Miller et al. 1998).



Palm warbler (*Dendroica palmarum*)

Both external and internal edges created by fragmentation can therefore result in significant effects to wildlife.

Source-sink dynamics

A related consequence to forest fragmentation and effects may be the creation of sink habitats by development processes. Source-sink dynamics refer to a variation of metapopulation structure whereby a species' population functions according to linkages between "source" and "sink" habitats. Source habitats occur where reproduction and recruitment are positive and therefore new emigrants are produced, while sink habitats occur where within-habitat reproduction is insufficient to balance local mortality, and these populations therefore would not persist without influx of immigrants from source populations (Pulliam 1988). Without adequate dispersal between sources and sinks, populations in sink habitat can become locally extinct.

Hansen et al. (2002) explored some of the ecological consequences of demographic change occurring in the Rocky Mountain West. They studied, in part, how development in rural areas of the West was influencing biodiversity in and around nature reserves. The authors found that bird species that either prey upon other birds or are brood parasites were more abundant near rural residential development than they were on adjacent nature reserves. Yellow warblers, in contrast, were negatively affected by rural residential development and demonstrated a negative relationship between nest success and density of homes within 6 km (Hansen et al. 2002). The authors concluded that their study area operated as a population sink for yellow warblers, where birds were constrained by climate at higher elevations and land use at lower elevations. The authors modeled population growth for yellow warbler to explore further and found that the study area was a strong population sink. They removed the effect of homes to simulate pre-settlement conditions, and found that the study area was projected to be a strong population source area, where population growth was negative only in the high elevation nature reserves. Their findings suggest that in pre-settlement times, emigrants from low elevation source areas were required to maintain a subpopulation of yellow warblers in Yellowstone National Park, suggesting that rural residential development in some low elevation areas possibly converted population source areas to population sinks for yellow warbler and other species (Hansen et al 2002). The authors point out the importance of these results in providing a mechanism whereby development outside of nature reserves may result in a reduction of species viability within reserves (Hansen et al. 2002).

Rogers and Allen (1987) pointed out a mechanism whereby rural development associated with towns may create sink areas for black bears. Areas of human use can act as sinks that result in a depletion of bears from surrounding areas because humans who are intolerant of bears kill them at unsustainable rates (Rogers and Allen 1987). Even at low population densities, bears are commonly attracted to human related food items in times when natural foods are in short supply (Rogers and Allen 1987). Black bear reproductive rates are primarily dependent on levels of natural foods, which fluctuate. Bear-human conflict is a common occurrence in rural towns in the Adirondacks and numbers of bear-related nuisance complaints increased by over 400% between 1993 and 2003 (Glennon, unpublished data). Because nuisance

problems created by bears can often become chronic and eventually result in the death of the bear due to human intolerance, areas of rural development with high incidence of human-bear conflict can become population sink areas for bears as they are killed at unsustainable rates. Rogers and Allen (1987) showed that the impact of Ely, MN on the surrounding bear population through illegal and nuisance kills of bears could be approximated as neutralizing population growth for a radius of 5.7km beyond the limits of the city.

Though not directly addressing a question of source-sink dynamics, Beckmann and Berger (2003b) investigated the effects of rural development on black bear populations by examining bear distribution and population parameters in urban-wildland interface areas and in adjacent wildland control areas in the Sierra Nevada. They found that bears in the urban interface areas were at much higher density, had larger body mass, smaller home ranges, and higher reproductive success than bears in the adjacent wildland control areas. However, wildland bears had more equal sex ratios and much higher dispersal success than bears in the urban interface. In control areas, 100% of cubs dispersed successfully, while only 17% of cubs dispersed successfully in the urban interface population, most of them suffering mortality as a result of vehicle collisions. Similarly, the authors found that the overall estimated bear population for the region differed little from previous estimates, and concluded that what was perceived as a large increase in the bear population was due instead to a radical shift of bears across the landscape created by the availability of garbage as a food source (Beckmann and Berger 2003b). These results also demonstrate how rural development in the Sierra Nevada region may be creating population sink areas for black bears.

Disruption of wildlife dispersal and movement patterns

The disruption of wildlife dispersal and movement patterns is a potential result of residential development on wildlife populations. Reduction and modification of native vegetation, interspersing of native habitats with openings created by lawns, and roads and/or paths built to access residential development may all result in reduced dispersal and movement for wildlife. Bolger et al. (1997) used principles of island biogeography to determine whether small native shrub fragments created by urbanization were able to support viable populations of native rodent species. The authors aimed to determine whether rodent populations isolated within fragments are viable over time, or are likely to eventually go extinct. More than half of the fragments they surveyed did not support populations of native rodents. Native shrub fragments isolated by urbanization were found to have fewer species than plots of equal size within unfragmented habitat, and older fragments supported fewer species than more recent fragments (Bolger et al. 1997). These results suggested that recolonization was not frequent enough to maintain rodent populations in these fragments and that local extinctions had occurred following isolation.

In another study focused on rodents, Bayne and Hobson (2000) investigated the relative use of contiguous and fragmented boreal forest by red squirrels. While this study focused on forest fragments isolated by agriculture rather than development or urbanization, the authors found that red squirrel abundance increased slightly with



Credit: C. Demers

Juvenile red squirrel (*Tamiasciurus hudsonicus*).

fragment size, and that squirrels were significantly more abundant in forest fragments than in continuous forest. The authors hypothesize that forest fragmentation may cause dispersing individuals to remain within patches until intraspecific competition forces them to leave the patch and disperse through the inhospitable open matrix. This pattern may have resulted in changes to red squirrel dispersal behavior that were responsible in part for the observed patterns of higher squirrel density within fragments (Bayne and Hobson 2000). The authors also point out that red squirrels are a significant predator on songbirds in many areas, and that higher red squirrel densities in remnant forest patches created by fragmentation may have particularly detrimental effects on songbirds in these areas (Bayne and Hobson 2000).

It is sometimes hypothesized that species with good dispersal capabilities should be least affected by habitat fragmentation because of their capabilities of moving among isolated fragments. Gibbs (1998) conducted a study to examine distributions of five species of woodland amphibians with differing life histories along a gradient of forest fragmentation in southern Connecticut. He found that, in contrast to prior expectations, dispersal ability was inversely related to fragmentation resistance. The redback salamander, the most sedentary of the species surveyed, was most resistant to fragmentation and found in greatest distribution along the gradient, while the most dispersive species, the red-spotted newt, was least resistant to fragmentation and did not persist below a forest cover threshold of approximately 50%. He hypothesized that, in fragmented habitats, most dispersing red-spotted newts probably end their dispersal movements in unsuitable habitats or become stranded in open habitats and thus, the high dispersal capability that allows this species to exploit ephemeral breeding areas in more contiguous habitats may become a detrimental trait in environments that are fragmented (Gibbs 1998).

Fahrig and Merriam (1994) discuss the relative importance of dispersal capabilities in a paper on conservation of fragmented populations, arguing that the spatial structure of the landscape is critical in understanding the effects of fragmentation on population survival. They point out that, in fragmented populations, local extinctions are common and that regional survival of these populations depends on recolonization. In a separate study, Fahrig and Paloheimo (1988a) explore the importance of demographic components on regional abundance in patchy environments by using model simulations. They show that dispersal is generally more important than demographics in determining regional population abundance. These findings point to the fact that landscape spatial structure is critical in understanding the effects of population subdivision on survival. Because landscape structure is dynamic, rapidly changing landscape structure can lead to increased distance and rate of dispersal.

Rates of change in dispersal must keep pace with rates of change in the landscape, or regional population survival will be compromised (Fahrig and Merriam 1994).

Effects associated with roads

Most of the above discussion relates to disruption of dispersal and movement patterns of wildlife species created by landscape scale fragmentation and resulting reduced movements between patches of available habitat. However, road construction and improvement are correlates of residential development and deserve a separate discussion as related both to disruption of wildlife movement and to direct mortality. Trombulak and Frissell (2000) provide a comprehensive review of the effects of roads on terrestrial and aquatic communities. In a review of the scientific literature on roads, the authors found that roads generally have detrimental effects on biotic integrity in both terrestrial and aquatic ecosystems. They highlight seven general effects of roads including:

- (1) mortality from road construction,
- (2) mortality from collision with vehicles,
- (3) modification of animal behavior,
- (4) alteration of the physical environment,
- (5) alteration of the chemical environment,
- (6) spread of exotics, and
- (7) increased use of areas by humans (Trombulak and Frissell 2000).

Construction of roads results in mortality for sessile and slow-moving organisms and can injure organisms adjacent to a road, in addition to altering the physical conditions around and beneath the road. Collisions with vehicles affect the population structure of many species of both vertebrates and invertebrates. Roads also alter animal behavior by causing changes in home ranges, movement, reproductive success, escape response, and physiological state. Roads themselves also cause many physical changes including altered soil density, temperature, soil water content, light levels, dust, surface waters, patterns of runoff, and sedimentation. Roads also add heavy metals such as lead, salts, organic molecules, ozone, and nutrients to roadside environments. Roads play a major role in the dispersal of exotic species by creating altered habitats, stressing native species, and providing movement corridors. Lastly, roads promote increased hunting, fishing, passive harassment of animals, and modifications to the landscape (Trombulak and Frissell 2000). The authors conclude that although not all species or systems are affected equally by roads, in general, roads are highly correlated with changes in species composition, changes in population size, and changes in the landscape processes that shape aquatic and riparian systems (Trombulak and Frissell 2000).

Three studies highlight the specific effects of roads on a number of taxa. Mader (1984) studied the effects of roads and fields on forest-dwelling mice and carabid beetles near Heidelberg, Germany. Both beetles and mice were captured and marked for an investigation of movements between sides of the road in the study location. The beetle population was almost completely divided into 2 subpopulations on either side of the road, and the author concluded that these specialized woodland carabids avoided penetrating the road edges and almost never or only rarely crossed the road. Roads constituted an even more significant barrier to mice in this study. None of the

original 121 marked and 35 recaptured mice were found to have crossed the road. At a different road location, mice were translocated from the left side of the road to the right side, and none of the 40 marked and released animals originally inhabiting the left side of the road were found to cross it again. Interestingly, Mader (1984) also found that even forest roads not open to public traffic appeared to be a significant barrier for both mice and beetles. Only 2 road crossings were observed, compared with 34 movements between adjoining trap lines in a control area.

Fahrig et al. (1995) investigated the effects of road traffic on amphibian density on road segments near Ottawa, Canada. Controlling for effects of date, local habitat, time, and region, the authors found that the number of dead and live frogs and toads per km decreased with increasing traffic intensity, the proportion of dead frogs and toads increased with increasing traffic intensity, and the density of frogs and toads, as measured by chorus intensity, decreased with increasing traffic intensity. They concluded that traffic mortality had a significant negative effect on the local density of anuran species (Fahrig et al. 1995).

Lastly, Gibbs and Shriver (2002) examined the effects of road mortality on turtle populations. They used modeling to simulate movements of small bodied pond turtles, large bodied pond turtles, and terrestrial and semi-terrestrial land turtles. By integrating road maps and traffic volume data with simulated movement patterns for these species, they could identify combinations of road density and traffic volume that produced particular levels of annual road mortality. They found land turtle populations in particular were potentially limited by road networks typical of the northeastern, southeastern, and central regions of the country. Their results indicate that road mortality is a significant component of habitat fragmentation for land turtles and therefore a potential contributor to their decline. Gibbs and Shriver (2002) point out that long-term research on turtles has indicated that as little as 2-3% additive annual mortality is higher than most turtle species are able to sustain and still maintain positive population growth rates. Because the age of first reproduction is significantly late for many turtle species relative to other fauna, and because road mortality may have a disproportionate effect on adults within the populations, the effects of road networks on land turtles in particular may be a limiting factor to population persistence.



Turtle crossing sign in the Adirondacks.

We can bring these findings home to bear on the Adirondacks by highlighting recent trends in traffic densities for this region. Percent change in traffic measured by the New York State Department of Transportation on nearly all major roadways in the Adirondack Park increased 25 – 200% between 1970 and 1990 (Jenkins and Keal

2004). Increased tourism, increased commuting, and greater numbers of people living in more remote places likely contribute to the increase. Increased traffic densities may have particular effects on reptile and amphibian communities in the Adirondacks.

Changes in community composition and structure

One of the most commonly observed patterns in studies of the effects of development on wildlife populations is that of changes in community composition and structure. A possible explanation for this pattern is that it is easier to observe changes in phenomena such as species richness and relative abundance, while studies to detect changes in parameters such as reproductive success and dispersal movements are much more time and effort intensive. Similarly, one of the most commonly studied taxa in urbanization research is birds, presumably because they are relatively easy to detect and sample. Several studies have examined the effects of urbanization on bird communities along gradients of increasing intensity of human habitation and use.

Germaine et al. (1998) examined relationships among breeding birds, habitat, and residential development in Tucson, AZ. Birds were divided into: (1) non-native species, (2) native species, and (3) a native indicator guild comprised of native birds dependent upon substrates with a high likelihood of disturbance as development increased. Species richness in both the nonnative and the indicator guilds was best explained by housing density, where area of native vegetative cover and distance from undisturbed washes were most closely related to richness of the native bird group. These results indicate that cover of native vegetation types is particularly important to native bird abundance and species diversity and that degradation and loss of native vegetation cover results in a higher proportion of nonnative species. Cam et al. (2000) investigated relative species richness and community completeness in bird communities along a gradient of urbanization in the mid-Atlantic states. Past research on the relationship between urbanization and species richness have either found that richness declines with increasing levels of urbanization, or that richness peaks at intermediate levels of urban development (Cam et al. 2000). Cam et al. (2000) found a negative relationship between relative species richness and proportion of urban land and average urban size of urban patches. This study points out the importance of considering species richness as it relates to the original species pool rather than as an absolute measure of diversity or biotic integrity. Clergeau et al. (2001) also found that bird species richness was negatively correlated with urbanization in a study encompassing areas in western France, northern Finland, and eastern Canada.

Several other studies have focused on changes in various faunal communities along gradients of increasing residential development or urbanization. Blair and Launer (1997), Blair (1999), Reynaud and Thioulouse (2000), and Germaine and Wakeling (2001) all found general patterns of increasing abundance and representation by generalist species and decreasing representation of more specialized species with increasing urbanization, in taxa ranging from birds to butterflies to lizards. In a single species study on dusky salamander, Orser and Shure (1972) found that densities of dusky salamander within streams were inversely proportional to the degree of urbanization and concluded that urbanization probably results in a disruption of the

trophic structure within streams by a reduction or loss of this species as a significant stream predator.

Two studies relating to the effects of increasing residential density on biotic communities have been conducted in the Adirondacks. Glennon (2002) examined small mammal communities in a stand level study encompassing a gradient from old growth forest, to managed forest, to areas of residential development. She found that small mammals responded to the gradient through changes in overall abundance and community structure rather than changes in indices of diversity or evenness. Total abundance of small mammals was highest in old growth forest areas and individual species demonstrated numerical responses to the gradient. These results demonstrated that use of diversity indices as diagnostics of ecological integrity may be misleading in some cases, suggesting that indices should be interpreted with caution in the absence of consideration of individual species' responses. In a second study, Glennon and Porter (2005) examined the response of bird communities to a gradient of human impact by testing the relationship of land use management types to an Index of Biotic Integrity (IBI) across the Adirondack landscape. In examining total, functional, structural, and compositional integrity along a gradient ranging from hamlets to wilderness areas, the researchers found that, in all cases, integrity was lowest in hamlet areas and increased to its highest level in wilderness. Further, the researchers found that bird community integrity was strongly related to roadlessness and that birds primarily responded to the distinction between developed and undeveloped land types. Half or more of the variability in the integrity index in a particular location could be explained by the distance from the nearest major road in combination with elevation and residential building density, indicating that large roadless blocks in the Adirondack Park are key to maintaining areas of high biological integrity.

All of the studies discussed above were conducted along gradients of increasing human habitation on the landscape and all investigated particular aspects of community composition and structure for varying taxa. Though most studies have been conducted on birds, a prevalent pattern appears to exist within birds and other taxa whereby increasing levels of urbanization or human habitation lead to increasing representation of generalist, human-adapted species and decreased representation of more specialized species. Depending on the ecological roles played by these more specialized species (e.g., top predators, pollinators, seed dispersers), this pattern could result in major impacts to biotic functionality in human dominated environments. For example, Engels and Sexton (1994) found that the generalist blue jay, an important nest predator, increases in abundance with urbanization and is found to be negatively correlated with abundance of the endangered golden-cheeked warbler, probably contributing to its decline. Similarly, the generalist red squirrel has been found to have elevated densities in habitat fragments such as those created by residential development and is hypothesized to have significant negative effects on nest success of breeding forest songbirds (Bayne and Hobson 2000).

Effects associated with domestic pets

A corollary of year-round, and sometimes seasonal, human habitation is the presence of domestic pets. The variety of shelter structures and food sources that accompany

human-dominated environments often result in elevated densities of small to mid-sized predators such as cats and dogs (Theobald et al. 1997). Domestic species such as cats and dogs have been found to have significant negative effects on native wildlife species (Churcher and Lawton 1987, Marzluff et al. 1998, Maestas et al. 2001). Ballard et al. (1999) investigated causes of white-tailed deer fawn mortality in north central New Brunswick, and found that domestic dogs accounted for 14% of the mortality on neonates. Miller et al. (2001) examined the responses of wildlife to pedestrians and dogs by measuring flushing and movement distances of mule deer and 3 songbird species exposed to hikers with dogs on and off trails. The authors found that, in general, responses were greater when activities occurred off-trail versus on-trail. American robins were least sensitive to pedestrians relative to the two grassland bird species investigated. Mule deer responded more strongly to pedestrians with dogs than pedestrians alone. The authors make suggestions for managing trails and permitted activities such that disturbances to wildlife may be minimized.



Domestic cats have also been shown to have significant effects to native wildlife in areas of human residence. Hawkins (1998) studied the effect of house cats on native birds and rodents in California and found that cats were contributing significantly to the decline of scrub-breeding songbirds. Crooks and Soulé (1999) also postulate a mechanism whereby housecats have contributed to the decline of songbirds through a trophic cascade mechanism in which widespread decline of the coyote,

combined with habitat fragmentation, has allowed for the expansion of smaller carnivores like housecats and resulted in negative effects to their avian prey. Soulé et al (1988) pointed out that animals such as cats and dogs may have disproportionate effects on wildlife because they will continue to prey on local species populations for longer periods than those populations are able to sustain them.

Effects associated with recreation in the surrounding area

Hansen et al. (2002) in their discussion of the ecological causes and consequences of demographic change in the New West, point out that there is a perception that a new economy in this region, based on high technology and outdoor recreation, is more consistent with conservation than is the traditional extraction-based economy. One of the primary reasons for the influx of immigrants to the west and other regions like the Adirondacks is enhanced recreational opportunities. However, initial studies suggest that the choices people make about where to live and play are resulting in altered ecosystem processes and biodiversity (Theobald 2000). Czech et al. (2000) point toward urban sprawl and outdoor recreation as the second and fourth leading causes of the decline in federally listed threatened and endangered species. Though studies on the effects to wildlife from outdoor recreation are few, initial studies from Colorado and other regions suggest strong potential impacts (Miller et al. 1998, Miller and Hobbs 2000, Hansen et al. 2002).

Miller et al. (1998) examined the influence of recreational trails on breeding bird communities in forest and mixed grass prairie ecosystems along the Front Range in Colorado. They examined species composition, nest predation, and brood parasitism by brown-headed cowbirds in areas near and away from existing trails. Bird species composition was found to be altered near trails in both of the ecosystem types, with a higher prevalence of generalist species near trails and decreased representation by specialist species. In grassland, birds were less likely to nest near trails. In both systems, nest predation was greater near trails and nest success greater away from trails. Brood parasitism was not found in the grassland ecosystem and was not influenced by trails in the forested system. In addition to showing trail effects, birds also exhibited distance effects, with a number of species in both ecosystem types showing increased abundance with increased distance from the trail. Miller et al. (1998) observed that, for most of the species found in reduced numbers near trails, the zone of influence of trails was approximately 75m.

Miller and Hobbs (2000) examined the effect of recreational trails on the risk of nest predation and nest predator activity in riparian habitat areas in Colorado. Specifically, the authors examined the relationship between predation rates on artificial nests and proximity to recreational trails. Their results showed significant differences in vulnerability to predation on transects near and away from trails and



found, in contrast to Miller et al. (1998), that predation rates increased with distance from trails. Because this study was conducted with the use of artificial nests, some information could be gained on the predators responsible for nest predation. Miller and Hobbs (2000) found that birds preyed on nests near trails more than they did away from trails, while mammals showed the opposite pattern. The contrast between the landscape setting of the two studies is important. Miller et al. (1998)

looked at more continuous habitats in two ecosystem types, while Miller and Hobbs (2000) examined riparian zones that could be effectively considered as consisting entirely of edge habitat because of their configuration. Miller and Hobbs (2000) conclude that the effect of trails and other narrow corridors on nesting success for woodland birds relies on more than the presence of a human-induced edge, and that differential nest predation rates reflect a suite of differing predator species with variable responses to recreational trails.

Other studies have also detected effects of recreation on breeding birds. Hickman (1990) examined the evidence for species' attraction to nature trails within deciduous forest and found that edge species such as blue jays and American robins were more abundant on sites with trails than those without trails. Rich et al. (1994) also found that avian nest predators responded and were attracted to narrow open corridors, potentially resulting in higher rates of nest predation near corridors such as trails.

Hahn and Hatfield (1995) found higher rates of brood parasitism in forest interior bird communities than on nearby old fields and edges, suggesting that cowbirds may switch habitats to take advantage of nontraditional hosts. Other studies have suggested that cowbirds respond to open corridors and use them as access routes into forest interiors (Miller et al. 1998).

Recreation may also influence breeding bird communities through human activity and disturbance (Miller et al. 1998). Studies by Van der Zande et al. (1984), and Van der Zande and Vos (1984) both found differential sensitivity and use by particular bird species along recreation trails dependent on levels of recreational activity. Additionally, Gutzwiller et al. (1994) detected effects of disturbance on bird behavior. These authors investigated the effects of human intrusions on song production in subalpine birds and found reduced singing activity in several species as a result of one person walking through the study site for a period of 1-2 hours. In a related study, Gutzwiller et al. (1997) examined the effects of repeated intrusion on the seasonal timing of song by males of three passerine species. This study had mixed results, with effects demonstrated on some parameters of seasonal song production but not all. The results of these studies together demonstrate the differential responses of species to non-mechanized human recreational activities such as hiking.

Mechanized recreation such as that by use of all-terrain vehicles (ATVs) and snowmobiles may result in substantially different effects to wildlife than those created by hikers. Creel et al. (2002) studied snowmobile activity and glucocorticoid stress responses in wolves and elk. They found that, for wolves, comparisons among populations and years showed that fecal glucocorticoid levels were higher in areas and times of heavy snowmobile use. For elk, daily variation in stress hormone levels paralleled variation in the number of snowmobiles. However, despite these stress responses, there was no evidence that current levels of snowmobile activity were affecting the population dynamics of either species. Other research on snowmobiles have demonstrated varying degrees of avoidance by white-tailed deer, mule deer, reindeer, and moose (Creel et al. 2002).

In sum, the effects of recreation on wildlife are varied and depend strongly on the type of recreational activity and the particular taxa being affected. However, in their review paper, Boyle and Samson (1985) concluded that, in 81% of the studies they reviewed, nonconsumptive outdoor recreation had negative effects on wildlife. The assumption, as Hansen et al. (2002) discuss, that an economy based on high technology and outdoor recreation is more consistent with conservation than is the traditional extraction-based economy may indeed be flawed.

Human-wildlife conflicts

Increasing rural development may also contribute toward increases in human-wildlife conflict (Baron 2004, Wolch et al. 1995). Reports of human-wildlife conflicts are increasing; a record 237,766 wildlife human conflicts were tallied by the United States Department of Agriculture in 2002 (Clayton, 2004). In Michigan, deer-related vehicle accidents increased from 56,666 in 1994 to 67,000 in 1997. In New Jersey between 1996 and 1997, complaints about bears increased by 40 percent. Mountain lion

complaints increased from about 4 per year in the 1980s to 115 between 1994 and 1996 in Oregon (Kenyon et al. 2004). While some attribute the increase in conflicts to changes in development patterns (e.g. Baron 2004, Wolch et al. 1995), little research explicitly defines human-wildlife conflict as a function of development patterns. It is reasonable to hypothesize that as people continue to spread into more remote and wild regions, interactions with wildlife will become more frequent. The increase in interactions will spur an increase in the demand for wildlife control (Conover 2002). As development increases and more human resources spread across the landscape, the populations of subsidized species (e.g. deer, coyote, or geese) - defined as “native species whose populations in some parts of their range are able to survive and, in some cases, expand in part due to resources provided by humans” - will increase (Mitchell and Klemens 2000, p7). In the Adirondack Park alone, the number of bear-related nuisance complaints to the New York State Department of Environmental Conservation increased by over 400% between 1993 and 2003 (Glennon, unpublished data). Often these subsidized species are the basis of many wildlife nuisance or damage complaints and the targets of control actions.

Negative complaints about wildlife tend to increase along a rural-to-urban gradient. A 1995 study examined a sample of wildlife complaints in New York State for 1989-



Credit: N. Kemerer

Bears around bird feeders are a common source of nuisance complaints.

90 (Curtis et al 1995). Results demonstrated that counties defined as urban (>200,000 people) and urban areas (homes on streets or blocks) in urban and rural counties have more wildlife complaints submitted to nuisance wildlife control operators than suburban (homes on roads, 50-130 homes/mi²) or rural (homes among farms and forests, 50 homes/mi²) areas. However, nuisance wildlife control operators subjectively differentiated among urban, suburban, and rural areas. The authors predicted that, during the study period in New York, approximately 6,435 wildlife complaints came from urban locations, 3,184 from suburban and 1,024 from rural areas. The per capita number of complaints by area was not provided in the study, but this may be increasingly important given the underlying density definitions of exurban development and trends toward this type of development.

Feeding and baiting of wildlife in areas of rural residential development may also occur as many residents have a desire to observe wildlife. Some people perceive that they are helping wildlife by providing additional food. Others may use bait stations to attract wildlife for hunting purposes. A comprehensive review of the ecological and human social effects of artificial feeding and baiting of wildlife is provided by the Canadian Cooperative Wildlife Health Center (2003). The authors demonstrate that significant ecological effects of providing feed to wildlife have been documented

through observation and experimentation at the individual, population, and community levels. Increased potential for disease transmission is of primary concern in some regions of Canada. However, other significant ecological concerns exist, and disruption of animal movement patterns and spatial distribution, alteration of community structure with reduced diversity and abundance, the introduction of invasive and exotic plant species, and general habitat degradation have all been documented at locations throughout North America.

More interactions between humans and wildlife are likely to occur as people continue to sprawl across the landscape, and the increase in interactions will spur an increase in the demand for wildlife control (Conover 2002). As development increases and more human resources spread across the landscape, the populations of subsidized species will increase. As discussed elsewhere in this document, when generalized or subsidized species populations increase, biotic integrity may be compromised. Often subsidized species are the basis of many wildlife nuisance or damage complaints and the targets of control actions. Much of the research pertaining to nuisance wildlife and human-wildlife interactions addresses which methods are best for controlling certain species (e.g., Forcey et al. 2004, Conover 2002), or what attitudes people have toward certain types of management (e.g., Siemer et al. 2003, Reiter et al. 1999, Decker and Brown 1987). Reliance on management and control practices to reduce human-wildlife conflict requires appropriate methods for physically manipulating animals and animal populations combined with changing behavior of many individual people. Any efforts to change individual human behavior must include methods to identify areas prone to human-wildlife conflict on the landscape and a framework to understand the suite of social-psychological processes that lead individuals to perceive human-wildlife conflict as positive or negative and ultimately influence behavior. Additionally, management and control practices coupled with attempts to change individual behaviors may not be adequate to alter human-wildlife conflict. Instead, assessing how the underlying land use pattern in an area might facilitate existence of particular species, and how those plans could be changed to maintain or promote biotic integrity will be crucial to addressing issues of human-wildlife conflict.

Studies conducted to address exurban development specifically

The majority of the studies described above come from work conducted in response to urbanization and/or fragmentation, or along rural-to-urban gradients. However, the aim of this paper is to describe the process of exurban development, and in fact, to characterize anything in the Adirondacks as “urban” may seem far-fetched. Attention to the phenomenon of exurban development is relatively recent, and most of the research has been conducted in the western United States. Much of the results of that research are in line with the studies already described. A treatment of studies focused specifically on exurbia is, however, warranted.

As is the case with studies of urbanization and fragmentation effects, most work has been conducted on birds. Perhaps because of ease of sampling, or perhaps because of concern over decline of neotropical migratory species in particular, birds are prevalent in studies of exurban development effects. Boren et al. (1999) examined avian community diversity in rural landscapes of differing human population density in

Oklahoma. They examined long-term changes in avian community composition as they related to historical and present land use, vegetation cover types, and landscape structure. The authors found that the amount of land in forest and that treated with fire or herbicides were related to avian community composition in the low density rural landscape. In the high density rural population area, the amount of land in deciduous forest, native grassland, and roads were related to avian community composition. Prairie habitat associated species were found in higher numbers in the low density rural population, while general habitat associated species were found in higher abundance in the high density rural population landscapes. The authors concluded that declines in numbers of neotropical migrants and increased representation of generalist species in the high density rural population landscape could be attributed to decreased native vegetation, road development, and increased landscape fragmentation (Boren et al. 1999). Though the authors of this study did not specifically refer to either of these landscapes as exurban, the population densities provided equate to a comparison of an exurban landscape (high density rural) to a rural landscape (low density rural) when placed within the human modification framework provided by Theobald (2004).

Odell et al. (2003) examined trends of rural residential development and the area of wildlife habitat affected by it, highlighting the zone of influence of residential development for a songbird community in mountain shrubland habitat. Researchers counted birds at survey points 30, 180, and 330m away from a residence into adjacent undeveloped land. They found that birds were either more abundant (human tolerant) or less abundant (human sensitive) near human habitation, with human tolerants tending to be generalists without narrow habitat or food needs (e.g., American robin). Human sensitive birds, characterized by very strict habitat and/or food requirements, were less abundant near development. The authors state that, "When development borders wild or undisturbed lands, a zone of up to 100m surrounding the development should be considered impacted habitat" (Odell et al. 2003, p79) and conclude that clustering development, and therefore allowing zones of influence around homes to overlap, can reduce the impact of exurban residential development on wildlife.

Bringing other taxa into the mix, Maestas et al. (2003) examined biodiversity across a rural land use gradient in Colorado, comparing avian, mesopredator, and plant communities across the gradient of increasing intensity of human use from nature reserves to cattle ranches to exurban developments. Maestas et al. (2003) found increased densities of human commensal species on exurban development relative to ranches or nature reserves, and higher densities of ground and shrub nesters on ranches and reserves than on exurban developments. Domestic dogs and cats were found almost exclusively on exurban developments, while coyotes were detected more on ranchlands than on exurban developments. In terms of plant community composition, ranches had higher native species richness and lower nonnative species richness and cover than did the other two types.

In a study similarly focused on a number of taxa, Odell and Knight (2001) studied songbird and medium-sized mammal communities associated with exurban

development in Pitkin County, Colorado, with two objectives of (1) determining whether a “house distance effect” exists, and (2) examining wildlife populations within exurban developments of different housing densities. They found altered avian densities up to 180m away from the homes on the perimeter of exurban developments, with a pattern of increased densities of human-adapted species and reduced densities of human-sensitive species near houses. Pets such as dogs and housecats were detected more frequently closer to exurban homes than farther away, while red foxes and coyotes were found in higher densities away from homes. The authors of this paper again make the argument that, from an ecological standpoint, clustering of residential development is preferable to dispersing houses across the landscape (Odell and Knight 2001).

Though not as numerous, studies have been conducted on taxa other than birds in areas of exurban development. In a paper that highlights, in part, the effects of exurban development on stream invertebrates, Nassauer et al. (2004) examined the effects of exurban residential subdivision development on water quality and public perception. The authors investigated theoretical future designs for exurban residential subdivision development in agricultural landscapes and their potential effects on aquatic ecosystems and public perceptions. They also asked whether better ecological quality of aquatic environments would correspond with public perceptions of greater landscape attractiveness. They explored three alternative exurban futures: ecologically beneficial subdivisions, conventional subdivisions, and conventional agriculture. They used a space-for-time substitution design, whereby the authors chose catchments that had existing land-cover analogs for alternative future design scenarios. They measured the chemistry and biota of first-order streams within these catchments and found that streams in catchments chosen to represent ecologically beneficial subdivision designs had the most total macroinvertebrate taxa, the most sensitive macroinvertebrate taxa, lowest nitrates, lowest total phosphorus, and lowest total suspended materials. To compare public perceptions of the alternative futures, 336 residents were surveyed in southeastern Michigan and asked to view images of simulated alternative futures and rate each landscape in terms of degree of naturalness, attractiveness, neatness, and apparent care. They found that ecologically beneficial futures were perceived as most attractive, and rankings of aquatic ecological quality were consistent with public perceptions of attractiveness (Nassauer et al. 2004).

A study on the effects of housing on mule deer and white-tailed deer in the Gallatin Valley of Montana showed a sharp decline in the mule deer population at low housing densities and little further impact on the population as the houses became more dense (Vogel 1989). Evenly distributed housing appeared to be more detrimental to the deer populations compared to alternative configurations. The study noted that as development occurred, white-tailed deer moved into areas previously considered mule deer range and that the deer using developed areas became more nocturnal and shifted habitat use. Vogel recommended increasing the density of housing in already developed areas, as opposed to low-density development in new areas.

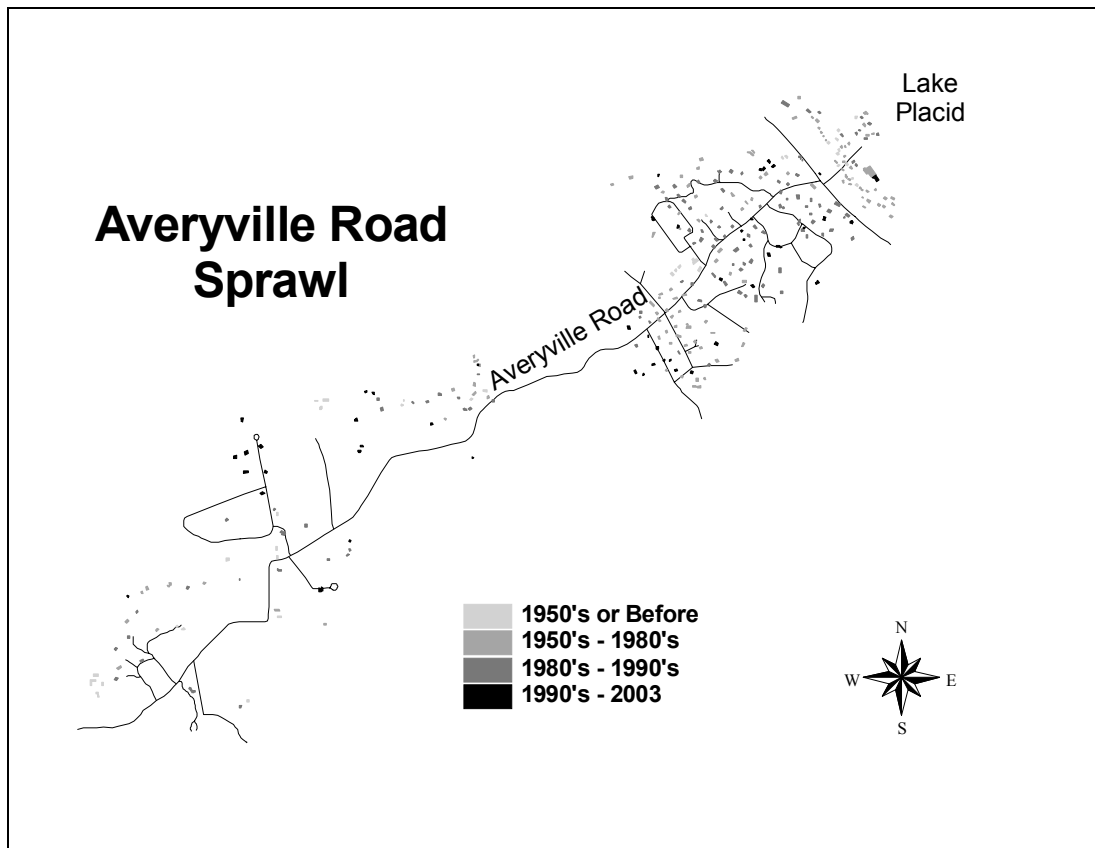
One additional review is worth highlighting. Though not an experimental study, Theobald's (2004) paper highlights the need to place exurban development and land use change within a framework of human modification. The author points out the emerging and encouraging trend of ecological research along the urban-rural gradient, but also emphasizes the need for clear definitions and quantitative metrics that capture important processes and patterns of land use and cover, and that more clearly place the research within a landscape context (Theobald 2004). The author emphasizes the need to distinguish between effects caused by the existence of certain land cover types versus the effects caused by use, and presents a Human Modification Framework that characterizes landscapes by the degree to which natural processes are free or controlled and landscape patterns are natural or artificial. Using this framework to place ecological work within the landscape context should contribute to better policy relevant science. Such work is necessary to ensure that ecological research can have a direct impact that better informs land use planning (Theobald 2004).

Cumulative impacts

The most critical aspect of the effects of exurban development on wildlife may be their cumulative impact. Very few researchers have found ways to successfully measure cumulative impacts, but the 'tyranny of many small decisions made singly' (Kahn 1966) is recognized. While each single land use change may result in a negligible impact, the accumulation of these individual changes over time within a landscape can result in a major impact. Exurban development and the associated loss, degradation, and fragmentation of wildlife habitat represents an example of the cumulative effects problem (Theobald et al. 1997).

In a comprehensive and elegant analysis, Theobald et al. (1997) provide a framework for beginning to understand the cumulative impacts of land use change on wildlife habitat. For the myriad of reasons discussed in this paper, development affects wildlife habitat both directly (e.g., construction of buildings and roads, loss of native vegetation, introduction of exotic species, fragmentation of habitat) and indirectly (e.g., hiking and other recreational activities, domestic pets). The building effect zone is the area around a residence within which wildlife habitat is adversely affected. The authors point out that two components of development are critical in understanding the potential impacts on habitat – density and pattern. This study examined seven different hypothetical subdivision designs ranging from dispersed to tightly clustered including: dispersed regular, dispersed irregular, dispersed random, dispersed half linear, clustered with four units, clustered with 16 units, and clustered with 22 units. Each subdivision was 258ha (640 acres). For each design, three indices were calculated: (1) disturbance zone – a measure of the area of disturbed habitat around the home, (2) the length of edge – the perimeter of all parcel boundaries in a subdivision (a measure of connectivity and landscape flow), and (3) perimeter to area ratio – a measure of shape. The researchers found that disturbance zone area increases rapidly with building effect distance, and, at distances beyond 200m, essentially no effective habitat exists for the dispersed-regular, dispersed-irregular, and dispersed half linear subdivision designs. The clustered subdivision patterns were found to have a much lower edge length and a much more compact shape

independent of building density, with substantially less area within the disturbance zone. In addition to the area of the disturbance zone, the spatial arrangement of structures determines how the disturbance zones will overlap and the relative degree of associated landscape fragmentation. Generally, the total area within the disturbance zone increases rapidly as building effect distance increases, and the overall subdivision pattern is often a stronger indicator of total disturbance zone area than density (Theobald et al. 1997).



Example of cumulative development, showing houses constructed between 1950 and 2003 along Averyville Rd. in Lake Placid. Map by A. Keal, WCS.

In their analysis, Theobald et al. (1997) found that a clustered subdivision (25% developed area), even with a density four times higher than the dispersed design, results in a substantially lower total disturbance zone area than a dispersed regular patterned subdivision. To further explore the interaction between density and subdivision pattern, the total disturbance zone within each quarter section of the subdivision was calculated for each combination of density, building effect distance, and pattern. Generally, these combinations produced nonlinear patterns, whereby the proportion of the quarter section within the disturbance zone increased very rapidly at low densities, and leveled off quickly as density increased. This matched the prediction of the authors that, even at low densities, development may cause substantial disturbance to wildlife habitat and disturbance increases rapidly with

small increases in density. Also as expected, the density at which substantial disturbance occurs decreases rapidly as building effect distance increases (Theobald et al. 1997).

Though they did not directly address cumulative impacts, Odell et al. (2003) did demonstrate the cumulative impacts of development in Pitkin county, Colorado (note: this paper is discussed above also, section 2.10). As part of an analysis to estimate overall loss of songbird habitat due to development, Odell et al. (2003) obtained parcel maps for Pitkin county and used the year of construction to identify developed parcels. Assuming a minimum zone of influence (analogous to “house distance effect” of Odell and Knight 2001, section 2.10 and the “building effect zone” described above by Theobald et al. 1997) of 100 m around each home, they mapped the zone of influence for each decade since 1950 and overlaid the zone of influence maps over vegetation maps to determine the habitat types falling within the zone and therefore those most affected by residential development over time. The results demonstrate an increasing trend within all habitat types examined because of sustained residential development within the county and demonstrate the cumulative impacts of development on wildlife habitat for 1950-2000.

One other analysis is directly relevant to the Adirondack Park. Glennon (2002) conducted an impact analysis for the Adirondack Park by modeling three potential scenarios including projections of (1) current development rates to the year 2050, (2) development resulting in buildout, whereby densities of buildings reach their legal limits and (3) current development rates to the year 2050 in which all new development is placed into only one of the five private land use classes in the Adirondack Park. Using estimates of average development rates generated by the Adirondack Park Agency and a regression analysis depicting the effects of building density, distance from roads, and elevation on biotic integrity (Glennon 2002, Glennon and Porter (2005), described in section 2.6), the authors modeled future effects to biotic integrity on the scale of a Breeding Bird Atlas block under these three scenarios (Glennon 2002). All three scenarios demonstrated significant effects to biotic integrity over time in the Park, and showed that biotic integrity declines most rapidly when development is channeled to areas of the Park that are currently characterized by open space uses. Though some may be more realistic than others, all three scenarios demonstrate the potential cumulative effects of development in the Park and highlight the degree to which private land is critical in this landscape.

POSSIBLE SOLUTIONS

Conservation planning at the local level

A full treatment of solutions to exurban development and best management practices for subdivision design is beyond the scope of this paper and the expertise of its authors. However, we will attempt to provide examples of tools and analyses that may be helpful in planning for future development in the most ecologically sustainable manner. Nationwide, state and federal policies such as income-tax deductions for mortgages and highway spending may promote sprawl. In the Adirondack Park,

reliance on density zoning has perhaps, while protecting open space, promoted the type of low-density exurban development described in this paper. Many local and county governments have a variety of mechanisms available to influence development and densities ranging from zoning, growth boundaries, building-permit limitations, residential moratoria, and infrastructure charges (Pendall 1999). In a 1999 study, Pendall hypothesized that different approaches to influencing development actually promoted more compact development. He tested the cumulative influence of different types of local land use controls on sprawl. The results showed that areas using land use controls to shift the cost of building infrastructure to support new development from the public to the builders reduced sprawl. Areas with mandated low-density zoning increased sprawl over time. Finally, areas whose local governments levy taxes to subsidize services and infrastructure based on the value of real property assessments sprawl more than those local governments who rely on a broader tax base. In areas undergoing rapid low density development and attracting outsiders, the local governments will be stressed fiscally to meet the new infrastructure demands and the demands from new residents for the municipalities to provide better services (Pendall 1999). The take home message suggested that mandated low-density zoning alone may not be the best way to promote compact developments. Communities, including the communities in the Adirondacks, need to rely on a variety of mechanisms at the state and local level to reduce low-density sprawl. This is especially important given the long-standing presence of the Adirondack Park Agency's zoning density regulations. With this system in place it is often easier for local communities to rely on that structure alone rather than taking a proactive approach to employ a variety of mechanisms to achieve development compatible with local natural features.

The case for clustering

One of the most commonly cited tools for combating the effects of exurban development is clustering. Odell et al. (2003) discuss the benefits of clustering, pointing out that clustered developments decrease fragmentation and perforation of habitats due to roads and houses, leaving the remainder of the landscape in a condition more suitable for wildlife sensitive to elevated human densities. For example, if houses on a large parcel of land were clustered on a small portion of its acreage with the remaining acres left undisturbed, wildlife communities would likely be characterized by a higher proportion of human sensitive species (Odell et al. 2003). Theobald et al. (1997) discuss the pitfalls of unclustered, dispersed low density developments in that they create maximum areal disturbance because disturbance zones do not coalesce until a relatively large building effect distance is reached. A clustered, low density development pattern, in contrast, causes minimal disturbance from an area standpoint (Theobald et al. 1997). Maestas et al. (2001), provide considerations for land-use decision makers and suggest that even at densities of one house per 14-20 ha (35-50 acres), the effects of human residences can be detected. Their research demonstrates the critical point that, "it cannot be assumed that, because most of the land within exurban developments remains undeveloped, it is suitable for all species that would occur there if houses were not present" (Maestas et al. 2001, p. 520). In fact, the analysis conducted by Hansen et al. (2002) demonstrated that residential development in some low elevation regions was capable

of converting a previous population source area to a population sink for species that are sensitive to rural residential development, and may have resulted in reduced viability of subpopulations on adjacent nature reserves as well. The case for clustering is made by numerous researchers (Arendt 1997, Theobald et al. 1997, Maestas et al. 2001, Odell and Knight 2001, Glennon 2002, Hansen et al. 2002, Odell et al. 2003, Glennon and Porter 2005).

Arendt (1997) provides some important guidelines for basing cluster techniques on development densities appropriate to the area. Though some of Arendt's (1997) suggestions are motivated by the case for saving productive agricultural lands, the same principles can be applied to clustering with the aim of protecting large blocks of unfragmented wildlands. The author suggests that in areas with significant resources, where low densities are appropriate, the development impact of, for example, five homes on 200 acres should be minimized by establishing maximum lot sizes of one to two acres, leaving the remaining 190-195 acres intact. An additional refinement currently being considered in Fauquier County, Virginia, is to supplement zoning with criteria governing the location on the property of the lots (Arendt 1997). The author uses examples from Montana and northern Michigan to demonstrate the mistake of limiting the number of new houses built in rural areas through ultra-low density standards without also setting maximum lot sizes or pattern criteria. In Montana, thousands of acres of productive rangeland have been turned into 40 acre "ranchettes," many of which are bought by weekend would-be ranchers with limited knowledge of rural land management (Arendt 1997). Likewise, in northern Michigan, productive orchards are being turned into 5, 10, and 15 acre parcels for sale to upscale buyers, maximizing the amount of land disturbed by development and taken out of production. Arendt (1997) argues for "conservation subdivision design" in areas with rural zoning densities in order to preserve open space and rural character.

While clustering can protect open space and reduce many negative impacts to wildlife, it is not a panacea. Hastings et al. (2004) compared the densities and nest success of human-sensitive and human-adapted birds on clustered developments, dispersed developments and undeveloped areas. The results showed that clustered communities supported avian communities more similar to dispersed developments than to undeveloped lands. Further, the researchers note that clustering may provide some advantage to certain human-adapted species, while other species will be negatively impacted. Given that clustered development may not provide a universal solution for impacts to wildlife, developments under consideration in the Adirondack Park should be considered in a broader ecological landscape context. Again, while not addressed in this study, developments should also be considered in the context of the long-term expected socio-economic impacts.

The Adirondack Park Agency Act does make reference to the use of clustering in both resource management and rural use areas. According to the Act, resource management areas "will allow for residential development on substantial acreages or in small clusters on carefully selected and well designed sites" (APA Act 1973, Section 805, p 14). Similarly, in rural use areas, "residential development and related

development and uses should occur on large lots or in relatively small clusters on carefully selected and well designed sites” (APA Act 1973, Section 805, p 15). However, despite the fact that the Act makes reference to clustering, no definitions of “substantial acreages,” “small clusters,” or “large lots” have ever been offered. Explicit definitions and parameters for these terms are needed. In addition, research on potential clustering designs and their impacts to wildlife and ecosystem attributes would greatly benefit planners and others considering cluster designs and recommendations in the Park.

Conservation subdivisions

In his book, “Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks,” Randall Arendt (1996) provides a process for designing a residential development around the central organizing principle of land conservation. The general message of his text is that the open space that is conserved in this way can be required to be laid out so that it will ultimately coalesce to create an interconnected network of protected lands. Arendt (1996) describes a methodology to rearrange density on each development parcel as it is being planned so that only half (or less) of the buildable land is consumed by houselots and streets. He maintains that, without controversial “down zoning,” or rezoning of a parcel of land to lower density, the same number of homes can be built in a less land-consumptive manner. Arendt (1996) argues that the density-neutral approach advocated in his book respects private property rights and the rights of developers, and allows for the accommodation of newcomers without undue impacts to the qualities that make communities desirable places to live.

Arendt’s (1996) conservation subdivision design process involves three basic steps:

- Step One: All potential conservation areas are identified. This step involves identifying and mapping of both “primary” and “secondary” conservation areas. Primary conservation areas include unbuildable areas such as wetlands, waterbodies, floodplains, and steep slopes. Secondary conservation areas include features such as mature woodlands, buffer areas around wetlands and waterbodies, critical wildlife habitat areas, and sites that may have historical or cultural significance. Primary conservation areas are deducted from the total parcel acreage.
- Step Two: Calculations are made to determine the number of dwellings allowed by zoning on the remaining parts of the parcel, after the acreage in primary conservation areas has been removed. These calculations include those areas that were designated as “secondary conservation areas.”
- Step Three: The permissible number of dwellings is then located around, but not within, the secondary conservation areas. During the actual design phase, after steps one and two have been completed, this stage will include locating house sites, designing street alignments and trails, and drawing in the lot lines. Arendt (1996) gives practical advice for this stage of the process as well.

The result of the conservation subdivision process is a density neutral subdivision with significant open space that would normally be developed. Though much of the

information in this book may be more helpful at a local level to community leaders within hamlets in the Park, two examples of conservation subdivision described in chapter 7: (1) a mostly wooded site at the base of the foothills, and (2) waterfront property beside a small northern lake, are particularly applicable to rural use and resource management zones in the Adirondacks. In addition, Arendt's (1999) book, "Growing Greener: Putting Conservation into Local Plans and Ordinances," provides additional information for local officials through a three-pronged strategy for shaping growth around a community's special natural and cultural features. It demonstrates ways of establishing or modifying (1) municipal comprehensive plans, (2) zoning ordinances, and (3) subdivision ordinances in ways which provide a strong conservation focus with open space protection as a central principle around which new development is designed.

Monitoring and predicting growth and tools for planning

The importance of monitoring and planning for future growth cannot be understated. Several papers have highlighted innovative ways in which particular regions have monitored, planned, and predicted future growth and enabled forward-thinking approaches for management. Hathout (2002) demonstrates the use of GIS for monitoring and predicting urban growth in Winnipeg, Manitoba, Canada, highlighting the effects of exurban development in the urban-rural fringe on agricultural land of East and West St. Paul. The author uses aerial photographs for 1960 and 1989 in order to map and predict changes in urban and agricultural land use and cover by using transitional probabilities of changes within and between land cover classes. The analysis highlighted significant losses of agricultural land to urban developments and the accelerating rate of exurban development north of Winnipeg during the study period. Lathrop and Bognar (1998) describe a case study of Sterling Forest, a 725 ha tract on the New York – New Jersey border that serves to link large watersheds in these two states. This paper highlights an example in which GIS and landscape ecology principles were used together to assess the environmental sensitivity of Sterling Forest lands and to prioritize lands for conservation protection.

Theobald (2003) describes a process for targeting conservation action by assessing levels of protection and exurban threats for the state of Colorado. He uses a modeling process to incorporate socioeconomic indicators of risk, including developed and roaded areas, and measures of the proportion of conservation lands affected by developed areas. This model is combined with a metric to measure the degree of fragmentation of patches caused by development. Theobald's (2003) model is a simplified version of a supply/demand/allocation model, based on practical assumptions and limitations of development. The supply component of the model describes the number of units available to be developed in an area, and the demand component defines the number of units likely to be needed in the future to meet the demands of projected changes to the population of the area. Levels of protection for different areas are determined by examining land ownership patterns. By combining information on protection levels with information on patterns of threats, Theobald (2003) was able to identify geographic areas where conservation action is most needed.

White et al. (1996) describe a technique for assessing risks to biodiversity from future landscape change in Monroe County, Pennsylvania. The authors used a map of current habitat of the area based on information derived from satellite imagery, in conjunction with six maps of future habitat distributions created from different land development scenarios. They considered all bird, mammal, reptile, and amphibian species in the study area and estimated area requirements for species using home ranges, sampled population densities, or genetic area requirements incorporating dispersal distances. Using species richness and habitat abundance as indices of biodiversity, they computed ratios of habitat abundance in each future landscape to current habitat abundance for each species. They found that modeled risks of loss of species in the study area were small using these types of analyses and available data, but that modeled risks of loss of habitat were substantial and generally greater for herpetofauna than for mammals or birds. The authors conclude that, for this study area, strategically designed future landscapes that focused on conservation and purchase of development rights had significantly lower risks to biodiversity than simple extrapolations from current development trends or zoning patterns (White et al. 1996).

Numerous examples also exist on the internet of efforts to evaluate landscape changes and their potential impacts to wildlife and habitat.

- The Exurban Change Program at Ohio State University (<http://aede.osu.edu/programs/exurbs/index.htm>): Analyzes economic, social, agricultural, and land use change throughout Ohio's townships, regions, and exurban/rural landscape. This website provides much information on exurban research in Ohio and links to other exurban information sources on the web.
- The New Jersey Landscape Project (<http://www.njfishandwildlife.com/ensp/landscape/index.htm>): A pro-active, ecosystem-level approach for the long-term protection of imperiled species and their important habitats in New Jersey.
- Beginning with Habitat (BWH; <http://www.beginningwithhabitat.org/index.html>): A habitat-based landscape approach to assessing wildlife and plant conservation needs and opportunities in the state of Maine. BWH provides each Maine town with a collection of maps and accompanying information depicting and describing various habitats of statewide and national significance found in the town that can help guide conservation of valuable habitats.
- The Ecological Planning and Design Directory of the Northeastern Illinois Planning Commission (<http://www.nipc.org/environment/sustainable/>): Provides a variety of tools in the form of documents pertaining to guidelines for all aspects of sustainable growth.

In addition to these resources, numerous documents provide guidelines for integrating ecological concerns into land use and development planning.

- "Ecological Principles and Guidelines for Managing the Use of Land," (Dale et al. 2000) – a discussion on principles of ecology that have implications for land use planning and rules of thumb for their practical application.

- “Habitat Protection Planning: Where the Wild Things Are” (Duerkson et al. 1997) – a handbook aimed at local governments, which provides information on managing development for people and wildlife.
- “Incorporating Biological Information in Local Land Use Decision Making: Designing a System for Conservation Planning” (Theobald et al. 2000) – a paper which describes an information system designed to support local scale conservation decisions by offering data over the Internet.
- “Practical Ecology for Planners, Developers, and Citizens” (Perlman and Milder 2005) – a concise and thorough overview of ecology and its application to meet the needs of land use professionals and citizens.

These are only a few examples of a wide variety of information sources available that can aid in the incorporation of ecological concerns in land use planning.

One particular tool that can be very powerful in land use planning and, particularly, in engaging the interest of local communities in better planning is the use of visualization tools. Theobald et al. (2000) make the very important point that planning for conservation is a process that uses scientific data, but which ultimately depends on the expression of human values. Nassauer et al. (2004) used visualizations of different future scenarios in southeastern Michigan to compare public perceptions of different subdivision designs and found that future scenarios designed to be ecologically beneficial were perceived as most attractive (section 2.10). In 2004, the journal *Ecological Applications* dedicated one volume to alternative-futures analysis for the Willamette River Basin in Oregon. Baker and Landers, Baker et al., Hulse et al., Berger and Bolte, Dole and Niemi, Van Sickle et al., and Schumaker et al. (2004) describe major components of the methods for alternative-futures analysis, as well as lessons learned from this approach. In the northeast, Ryan (2002) used a photo-questionnaire to document residents’ preferences for housing developments. His findings indicated that residents have different perceptions of development compatible with the rural landscape. Placement of open space around a development and the apparent densities of the development (as seen in the photographs) altered respondents’ perceptions. The Vermont Forum on Sprawl (VFS) has used numerous visualization techniques to demonstrate the potential changes in the land under a variety of development scenarios (VFS 1998b). Even though Vermonters valued environmental qualities and disliked sprawl, if given the option they would chose to live in a sparsely settled area outside of town (VFS 1998a). Communicating with stakeholders and understanding their perspectives as well as providing education about the potential results of their choices, will drive and possibly alter the demand for different types of development. Allowing stakeholders to visualize realistic possible futures for their region can do much to generate enthusiasm for better land use planning.

CONCLUSIONS

Caveats

It is important to point out that the majority of the work described above took place in landscapes more urbanized than the Adirondacks, and indeed many were conducted along rural-to-urban gradients in an effort to ascertain the effects of increasing human impacts on wildlife populations. The extent to which any development in the Adirondacks could be described as urban is in question. However, results of studies in exurban areas, which are more relevant to the Adirondack Park, are very similar to those resulting from studies of true urban habitats. It may be that changes associated with low density, exurban development are representative of a point on the continuum between wild, undisturbed lands and urban, highly disturbed areas. It is possible that the effects of residential development on wildlife populations share some similarities across a wide variety of landscapes and levels of urbanization. This certainly seems to be the case with respect to some aspects of community changes, namely those reflected in increasing proportions of generalist, human-adapted species and decreasing representation by more specialized species. This pattern has been noted in studies from many regions, including the Adirondacks, and widespread concern exists over what is perceived as the resulting simplification of ecosystems.

A second caveat that is important to mention here is that the majority of the work that has been conducted with the specific purpose of addressing exurban landscapes has come from the western United States. Though observed patterns mimic many of those seen in studies conducted in other parts of the country and world, the extent to which the results of these studies apply in the Adirondacks is unknown. Western ecosystems are sufficiently different from northeast temperate forests that it is possible that differences may exist in the response of wildlife to residential development. For example, Odell and Knight (2001) found a “house distance effect” of 180m, inside of which the environment could be considered to be altered, by virtue of the presence of human habitation. It is unknown whether the same pattern would be found in the Adirondack Park. Research on building effect distances is much needed in the Adirondacks and other eastern regions. Research highlighted in this paper has also come largely from studies of primary residences. The Adirondacks have a large proportion of ownership in second homes and seasonal residences. Elucidation of the differences between the effects to wildlife from seasonal and permanent occupancy is also an example of needed research.

Suggestions for next steps in the Adirondacks

Given the above caveats, some recommendations can be made with respect to the Adirondack Park. On a landscape scale, the critical importance of private land must be recognized in the Adirondacks. Numerous authors have argued for the importance of private land in the maintenance of biological diversity, both inside and out of the Park (Knight 1999, Maestas et al. 2001, Odell and Knight 2001, Glennon 2002, Hansen et al. 2002, Hansen and Rotella 2002, Hilty and Merenlender 2003). Private lands in general harbor significant amounts of biological diversity, at least some

habitat for 95% of the federally listed species in the U.S. (Hilty and Merenlender 2003). In addition, nature reserves in general are disproportionately located at higher elevations and on less fertile soils, while the most productive landscapes occur largely on private lands (Scott et al. 2001).

Though the Adirondack Park has one of the most progressive set of protections for public land anywhere, private lands remain a critical component to the long-term maintenance of biotic integrity in this landscape (Glennon 2002). Public land in the Adirondacks provides for vast acreages of roadless forest that are invaluable for wildlife and ecosystem function. Private land, however, is subject to a myriad of uses and impacts and, although it too is protected by strict land use regulation, private land plays a critical role in providing for some of the unique biological features that characterize the Adirondack Park (e.g., boreal habitat). Private and public lands must be considered simultaneously as activities on one can have profound effects on the other (Hansen and Rotella 2002). Though extensive efforts have now been made to protect vast areas of private lands from development through conservation easements, pressures for development on remaining lands are very high and will continue to be so given the decline in available waterfront properties and current escalating property values in those same areas. Careful planning that allows development of the private land in the Adirondacks without sacrificing ecological considerations can go far toward protecting not only the biotic integrity of these lands, but the aesthetic resources that make them desirable for the millions of visitors that enable the economy of the Park to operate. Analyses conducted on a Park-wide scale to identify regions that are particularly vulnerable to future development, and consideration of them in the context of the rest of the Adirondack landscape, would provide valuable information for planning to protect biological diversity and ecological integrity on a landscape scale.

Apart from a consideration of the importance of private lands in the Adirondack Park, powerful suggestions have already been made by Adirondack Park Agency (APA) staff members that provide a substantial baseline of needed information for planning. The Adirondack Park Trends Analysis Plan, outlined by the APA in 1991, was aimed at development of a Park-wide database that could be used to monitor trends in Park resources. It included recommendations for monitoring resources in four categories:

- (1) Economic, fiscal, and cultural (e.g., public service, housing),
- (2) Park character (e.g., open space, scenic vistas, travel corridors, community character),
- (3) Physical (e.g., surface water, ground water, air resources), and
- (4) Biological resources (e.g., forested lands, vulnerable lands, shorelines, wetlands).

If careful monitoring of all of the resources outlined in the Adirondack Park Trends Analysis plan were implemented, Park planners would be extremely well prepared to face the challenges represented by exurban development.

The American Planning Association provides a set of basic principles for protecting wildlife on landscape and local scales (Elliot 1998). Many of these same principles

are echoed in the recommendations of Curran (1991). At a landscape scale, the American Planning Association suggests planners should:

- “Maintain large, intact patches of native vegetation by preventing fragmentation of those patches by development. If all other values of habitat are equal, larger patches of habitat should be protected in preference to smaller ones.
- Establish priorities for species protection and protect habitats that constrain the distribution and abundance of those species.
- Protect rare landscape elements. Guide development toward areas of landscape containing “common” features.
- Maintain connections among wildlife habitats by identifying and protecting corridors for movement. Identify and protect small patches of vegetation that provide “stepping stones” among large, core patches described above.
- Maintain significant ecological processes in protected areas. Examples of ecological processes include periodic fires, floods, and scattering of habitat materials by wind.
- Contribute to the regional persistence of rare species by protecting some of their habitat locally. In other words, local communities need to ‘think regionally, and act locally.’
- Balance the opportunity for recreation by the public with the habitat needs of wildlife. Assure that some protected areas remain in private ownership not open to the public, in order to reduce the intensity of use by recreationists. Regulate recreational use of protected habitat on public land to minimize impacts on sensitive species” (Elliot 1998, <http://www.planning.org/thecommissioner/19952003/spring98.htm>, accessed on 3/7/2005).

On a local scale, many of the tools outlined and highlighted in this paper could be used to structure and plan development within hamlets in the Park in ways that would allow not only for greater conservation of resources, but would again protect the aesthetic resources that make our hamlets attractive for primary and second-home owners as places to live and recreate. A different set of principles apply at local scales (Elliot 1998). For protecting wildlife when planning development at the site scale, the American Planning Association recommends planners should:

- “Maintain buffers between areas dominated by human activities and core areas of wildlife habitat. Limit human activities to one or more buffer zones surrounding a core area, with more intense activities restricted to more distant zones. If people must pass through the core area on foot or bicycle, limit them to a well-defined trail.
- Facilitate wildlife movement across areas dominated by human activities. Provide alternatives to crossing busy roads, such as underpasses, especially during road construction. Minimize fencing types that inhibit the movement of wildlife species that are likely to occur in the area.

- Minimize human contact with large native predators. Prevent wildlife from associating food with humans by exercising tight control over potential sources of nourishment such as garbage or food for domestic animals.
- Control numbers of mid-sized predators, such as some pets and other species associated with human dominated areas. Prevent domestic pets, especially dogs and cats, from roaming freely. As an alternative provide designated areas where people can exercise or “run” their pets.
- Mimic features of the natural local landscape in developed areas. Keep levels of disturbance to trees, the understory, and other structural features to a minimum during construction. Design house lots in a fashion consistent with local natural habitats-by using native vegetation, for instance” (Elliot 1998, <http://www.planning.org/thecommissioner/19952003/spring98.htm>, accessed on 3/7/2005).

Though these recommendations may not have universal appeal, they provide guidelines that can be used by planners and local government at both the landscape and local scales to protect biological diversity and wildlife resources in the face of exurban development pressures in the Adirondack Park.

Conclusion

Throughout this piece we have made numerous recommendations about potential research projects that would greatly benefit future planning, development, and conservation efforts in the Adirondack Park. We hope that these recommendations will come to fruition through our research efforts at the Wildlife Conservation Society, coupled with collaborative efforts with regional organizations and universities. Our recommendations for research are summarized here:

- Determining an appropriate building effect distance for the Adirondacks and other eastern regions.
- Examining the differences between the effects to wildlife from seasonal and permanent occupancy.
- Identifying regions across the Park most vulnerable to future development.
- Implementing a consistent and well-designed monitoring system of socio-economic, cultural, aesthetic, physical and biological resources.
- Evaluating residents’ values, attitudes, and perceptions toward wildlife and human-wildlife interactions.
- Understanding residents’ expectations for housing placement and landscape qualities.
- Developing methods to allow stakeholders to visualize realistic future development impacts and alternatives.
- Researching potential clustering designs for new developments and their potential impacts to wildlife and ecosystems.

Although not explicitly addressed in this paper, we reiterate the importance of understanding the implications of exurban development on the socio-economic conditions of Adirondack communities. We provide a cursory overview of the human

aspects related to this type of development. More in-depth review of existing literature and basic research will be necessary to fully understand the societal implications of continued exurban development. As emphasized by current WCS projects, combining social and ecological research is critically important for addressing the conservation issues facing the Adirondack Park.

It is hoped that this paper provides information that can be useful in evaluating the potential effects of development on wildlife species and thinking critically about how local governments and organizations may influence these impacts through decisions made at the town, county, and regional level. The Adirondack Park remains one of the very rare places on the planet where the opportunity to carefully plan for the protection of wildlife and habitats remains. We hope that this paper provides a catalyst for opening the dialogue about low-density development impacts and inspiring research to understand and mitigate negative impacts and ultimately improve the Adirondack Park's human and biological communities.

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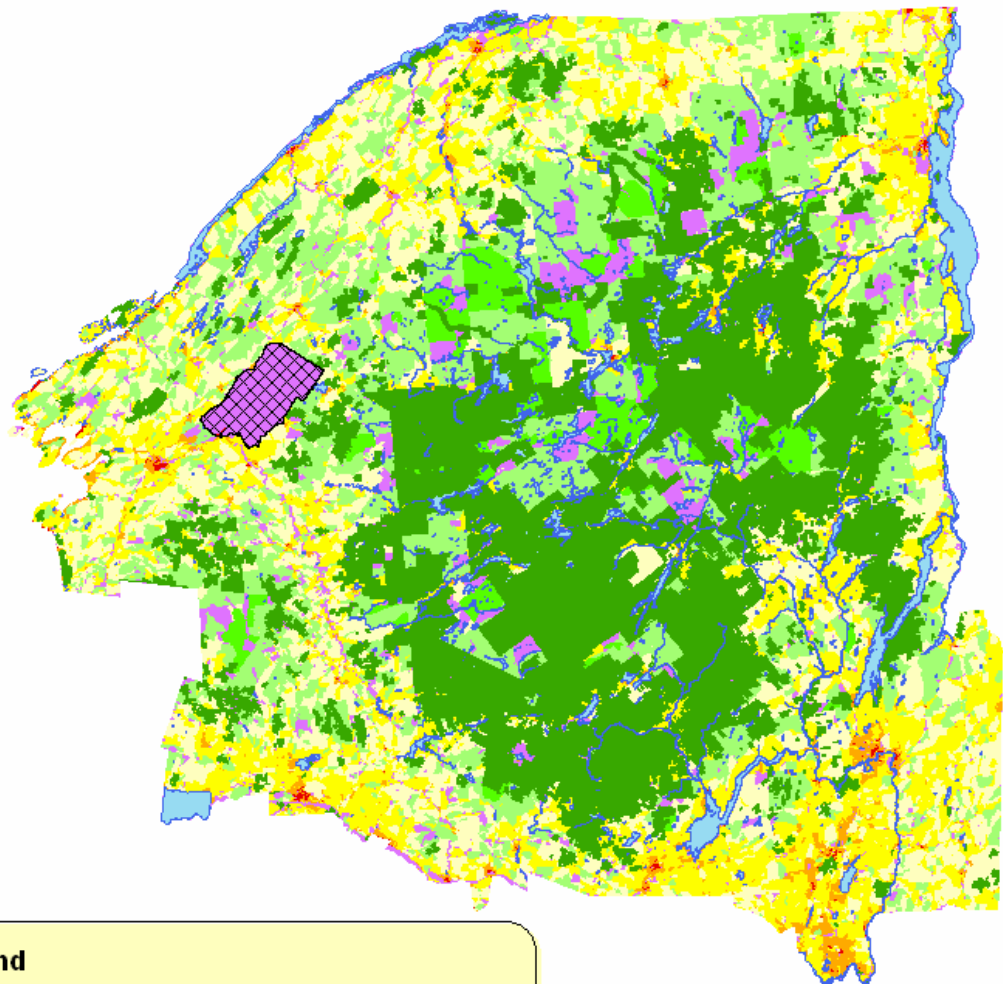
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Northern New York Land Classifications by Census Block



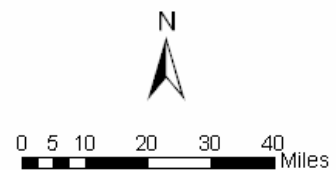
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Census Blocks Areas

Acres per House

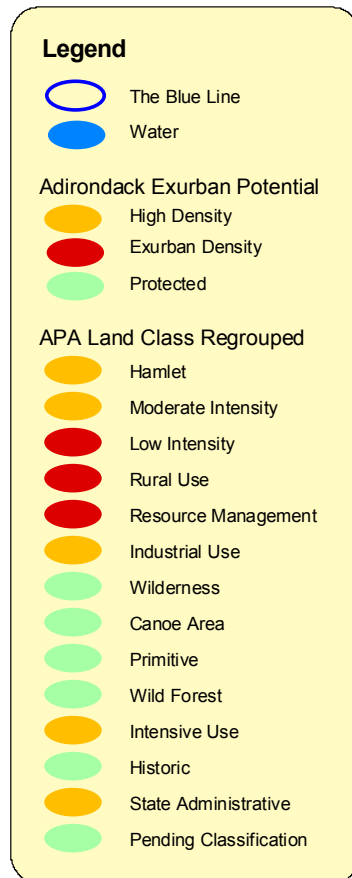
Urban	0.00 - 0.40
Suburban	0.41 - 5.00
Exurban	5.01 - 40.00
Rural	40.01 - 100.00
Rural	100.01 - 1000
Wildland	1000.01 - 9000
n/a	

Water
Fort Drum
Protected



Map By: Heidi Kretser
Source Data: U.S. Census Bureau 2000
and NYS GAP 1999

Adirondack Park Agency Land Use and Development Map: Exurban Classifications



Map By: Heidi Kretser
Source Data: Adirondack Park Agency 2001

