Land use change in Northern Forests: Assessments and recommendations for conserving biodiversity

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Completion date: Dec 1, 2007

Take Home Message:

A baseline for monitoring the effects of land use change on wildlife species has been established. Housing and development projections in Vermont for the year 2020 appear slight; nonetheless these changes can have dramatic consequences for species such as black bear.

Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the USDA Forest Service. <http://www.uvm.edu/envnr/nsrc/>

Project Summary

- **Rationale**: Land use change involves the conversion of one land cover type to another, and often results in the loss and fragmentation of existing wildlife habitat. Although large areas of contiguous habitat still remain in the Northern Forest , increasing development pressures results in the conversion of forests land types to urban, suburban, or exurban land types. These trends indicate that research focused on understanding the impacts of land use change on the region's native flora and fauna is much needed.
- **Methods**: In 2003-2004, we surveyed plants and animals at 168 sites across Vermont. The full dataset consists of 36,000 bird records, 7,000 amphibian/reptile records, several hundred carnivore records, and several thousand invertebrate records and tree records. Survey methods were taxon-specific. The analysis consisted of 3 steps. First, we analyzed data for vertebrates on a species-by-species basis with a single-season occupancy modeling framework, using landscape variables from 2001 National Land Cover Data as covariates. Second, we used data projections of how human housing density in Vermont will change between 2000 and 2020 at each of the wildlife survey sites, and predicted how changes in housing would increase development and decrease forest cover at each site in two scenarios (traditional growth and sprawling growth). Third, we quantified how probability of occupancy at a site is expected to change between 2000 and 2020 as a result of development. We present results on black bears to illustrate our approach.
- **Major findings** The probability that a site will be occupied by black bears was positively related to the percentage of forest within 5 km of a study site, and negatively related to the percentage of development within 5 km of a study site. Sites with >15% development had < 10% chance of being occupied by a black bear. The total increase in housing units within 5 km of the black bear study sites in Vermont was conservatively projected to be 12,107 units. The average housing growth rate across all black bear sampling points was 1.13, or 13% growth over baseline 2000 values. Total increases in housing units were concentrated in sites with low percent development in 2000. As a result of increased housing, sites were projected to have increased percent of development and decrease in forest cover, thus negatively affecting black bear occurrence. In the traditional growth scenario, on average, there was projected to be a 5% decline in the probability that a site will be occupied by black bear compared to baseline measures in 2000. In the sprawl scenario where development occurs at a 240% pace than human growth, there was projected to be a 18% decline in probability that a site would be occupied compared to baseline measures in 2000.
- **Implications for the Northern Forest region**: Wildlife species such as the black bear often have habitat "thresholds" beyond which probability of occurrence declines precipitously. In Vermont, this threshold for black bears occurs in landscapes with > 15% development. Most of Vermont currently has < 15% development, but areas with the largest housing growth rates are projected to occur in primarily undeveloped sites. These results indicate that biodiversity planning should be an important element for land use planning in the Northern Forest region.

Background and Justification

- Loss of biodiversity due to forest fragmentation and development is a highly salient issue in Vermont. Although large areas of contiguous forest still remain, increasing development pressures, spurred by demand for recreational property, increasing land value, and economic pressures on forest landowners, threaten to further degrade the landscape. A study by the Vermont Forum on Sprawl (1999) suggests the magnitude of the growth problem in Vermont. Residential densities are declining and land consumption per capita is increasing, with the rate of land development ~ 260% greater than the rate of population growth. This trend has manifested itself in a decline in the population share of town centers and an increase in newly created suburban communities. About 40% of that development occurred on farmlands, while much of the remaining development is occurring in forestlands. Between 1982 and 1992, the fastest growing type of development was a category known as “small urban built up,” which refers to small, unconnected blocks of land that develop within a matrix of less developed land. This pattern is a particularly effective facilitator of fragmentation. These trends indicate that research that aims to understand the impacts of such development on the region’s biological resources is much needed. Indeed, recommendations on preserving the future of the Northern Forest given by the Governor's Task Force on Northern Forest Lands are mainly large-scale political and legal strategies that might be used to curb or lessen development pressure.

Background and Justification

- Because of their large area requirements, and correspondingly low densities, wide ranging mammalian species such as the black bear are sensitive to habitat fragmentation, disturbance, and exploitation by humans. This combination of attributes—ecological importance and vulnerability in the face of habitat change, disturbance, and exploitation—make it imperative for researchers, managers, and planners to understand the factors that affect distribution, habitat-use, and demography of wide-ranging mammals. The ability of resource managers to predict how these species respond to a changing landscape, and to identify the habitat components that are most important for their persistence, may be of great consequence to their conservation in the face of future human development.

Photo Credit: www.exzooberance.com

Objectives

- **Objective 1**. Conduct coordinated assessments of black bear occurrence in Vermont.
- **Objective 2**. Develop mathematical models to predict the probability of occurrence of black bears statewide.
- **Objective 3**. Identify how projected changes in housing density in Vermont in the year 2020 will alter the distribution and occurrence of black bears.

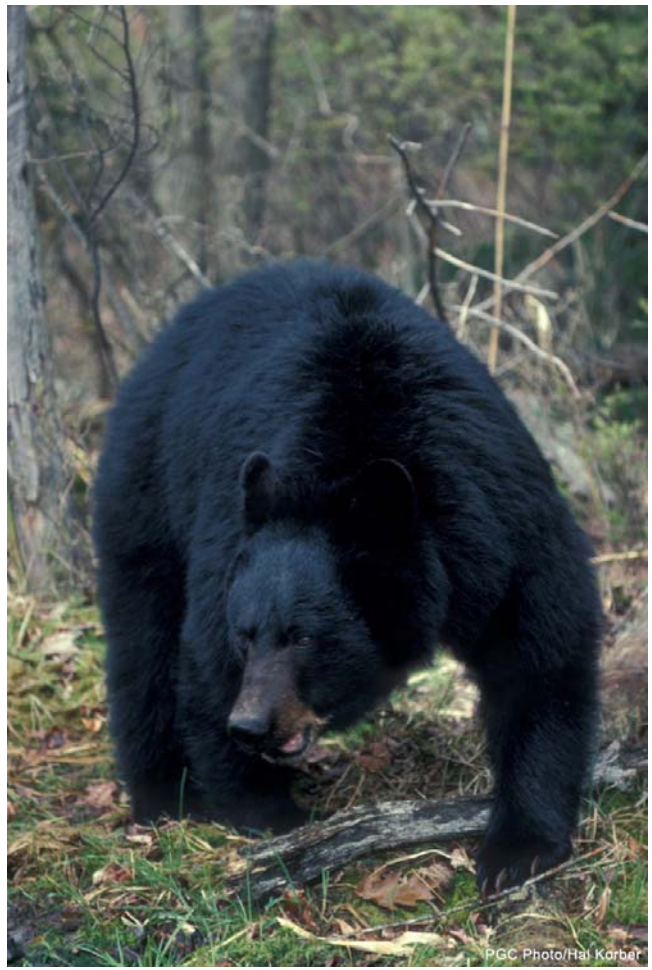
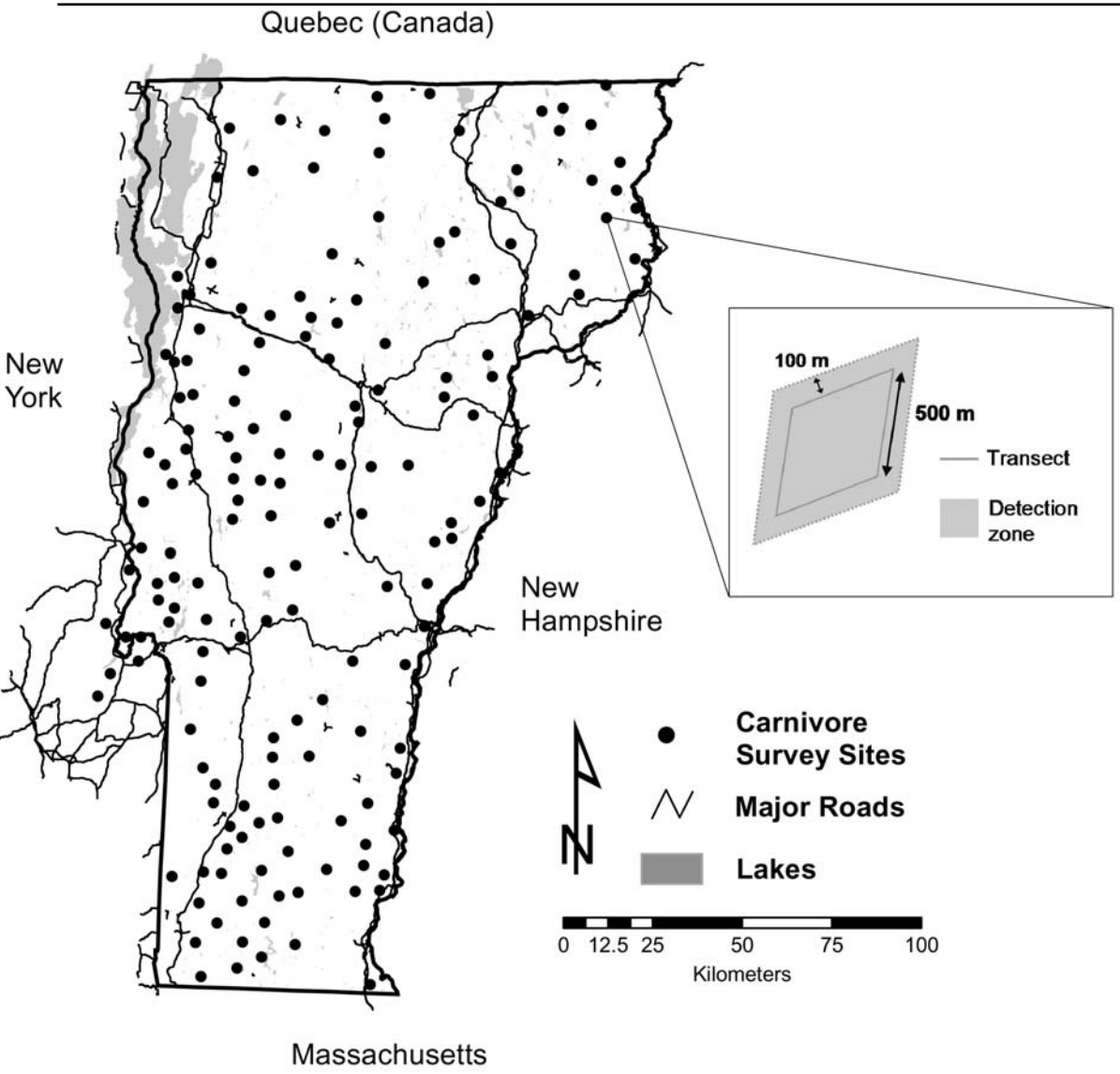


Photo Credit: Pennsylvania Game Commission

Methods

Survey Wildlife Species at 168 Sites throughout State of Vermont in 2003-2004



Methods

Study Species: Native Carnivores, Songbirds, and Amphibians

Though data were collected for additional species, this report will focus on black bears.

CARNIVORES

American Black Bear

Tom Brakefield © California Academy of Sciences

Fisher

Bobcat

Gerald & Buff Corsi © California Academy of Sciences

SONGBIRDS

AMPHIBIANS

Methods

Carnivore Survey Protocols

- **Field Data**: Detection or non-detection of black bears at each site with cameras, hair snares, and dogs.
  - **Remote Cameras**:
    - Sensor (single or dual).
    - Target species attracted by bait and scent lure.
    - Deployed for 14 days.
  - **Hair Snares**:
    - Carpet pad with barbed nails
    - Fastened to tree at approximately 50cm
    - Baited with a scent lure
    - Deployed for 14 days
  - **Scat Detection Dogs**:
    - Dogs trained to detect black bear, bobcat, and fisher scat scents.
    - Training methods similar to those used to train professional “drug-sniffing” dogs.

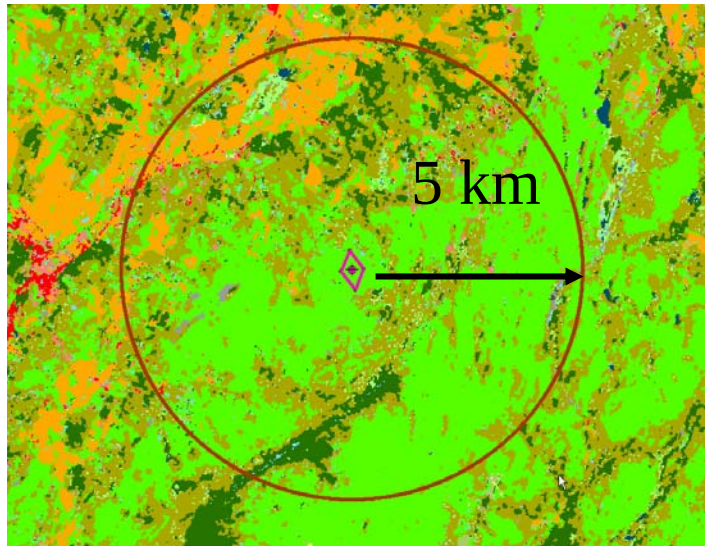
Methods

Obtain remotely sensed data associated with each site.

- GIS data: primary source is 2002 landuse-landcover data from UVM Spatial Analysis Lab.

- Percent cover of 6 different land categories in each 5 km circle was determined:
  - Forest (mixed + deciduous + coniferous + woody wetlands)
  - Deciduous forest only
  - Core forest (forest > 100m from edge)
  - Conserved lands
  - Wetland
  - Developed (all developed land classes, including commercial development and housing)
  - Large roads (linear meters of roads per area)

Five km buffer surrounding a single study site. All analyses were conducted with data representing a 5 km spatial scale.



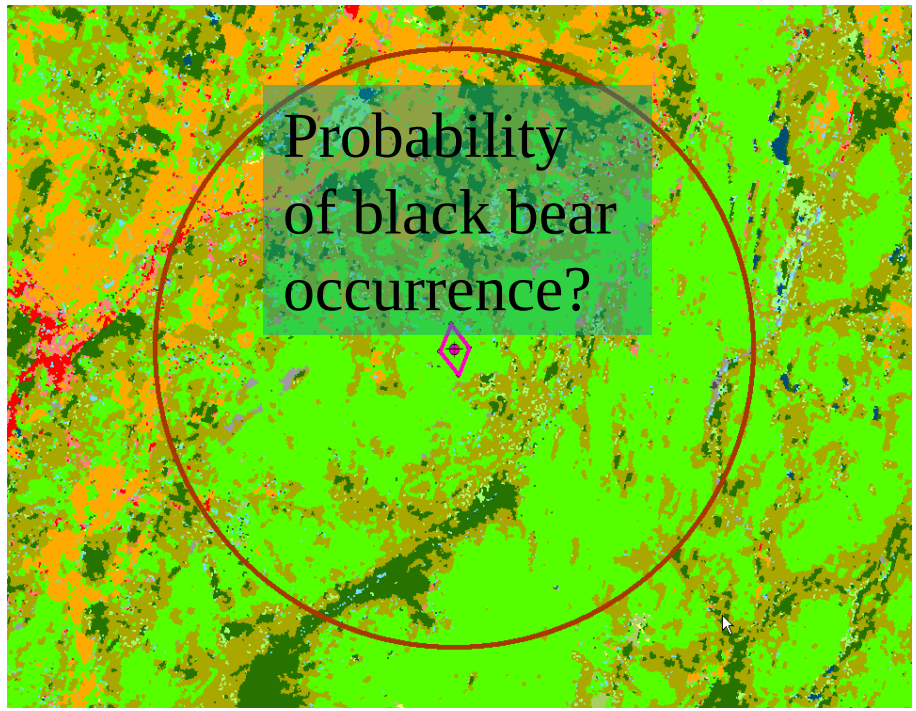
- Statistics summarizing the land cover characteristics of the study sites are provided in table below.

Simple Statistics					
Variable	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
% Forest	162	70.5	21.9	5.2	95.0
% Core Forest	162	50.6	25.3	0.0	93.5
% Conserved Lands	162	26.1	28.0	0.0	99.5
% Deciduous Forest	162	38.4	18.2	2.8	75.2
% Developed	162	4.8	4.1	0.3	30.4
% Wetlands	162	1.7	2.0	0.0	15.0
Large Road Density	162	0.4	0.3	0.0	1.6

Methods

Develop mathematical models that predict the probability that a site will be occupied by black bears.

- Use occupancy estimation and modeling procedures to develop predictive models of occurrence for black bears.
- Key output is the probability that a given site will be occupied by bears.
- Probabilities range between 0 and 1.0.
- Citation: MacKenzie, D.I., J.D. Nichols, G.B. Lachman, S. Droege, J.A. Royle and C.A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248-255.



Five km buffer surrounding a single study site. All analyses were conducted with data representing a 5 km spatial scale.

Results

Camera Detections of Black Bear at Study Sites

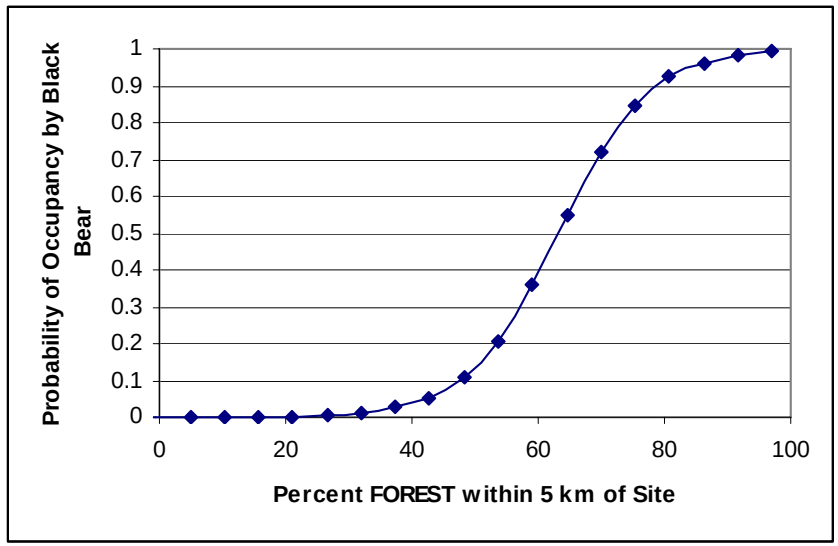


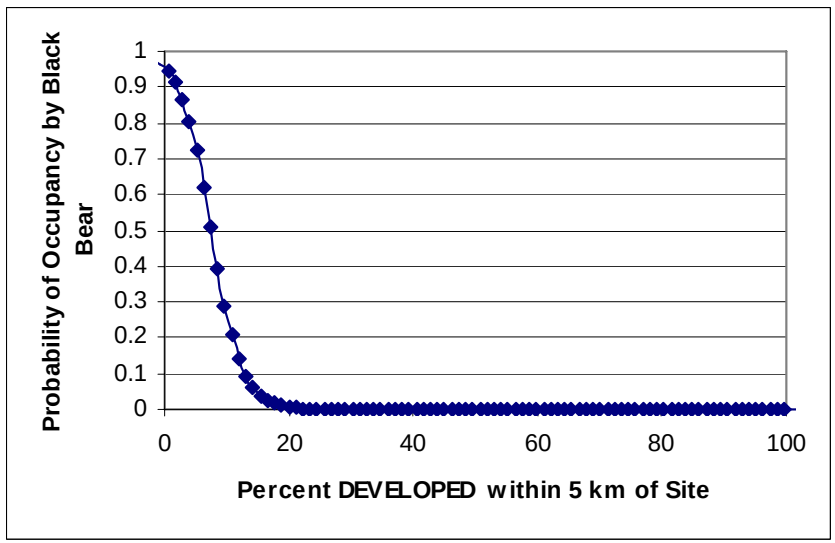



Results

Probability of occurrence of black bear in Vermont; 2003-2004

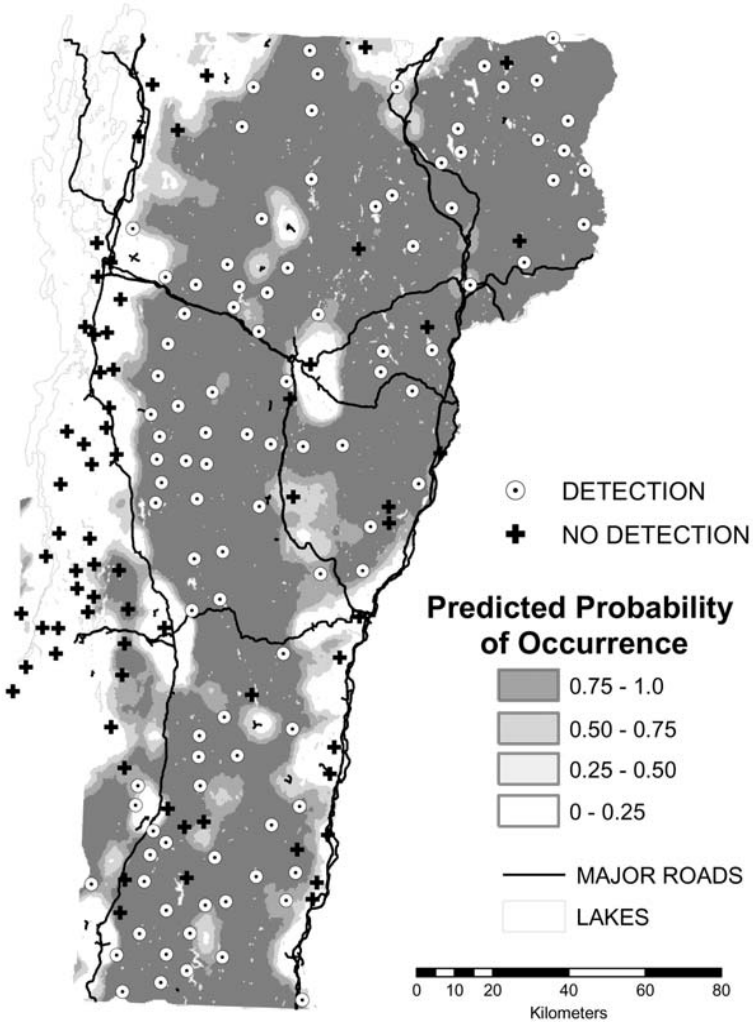
- **Black bears** were detected at 101/168 sites.
- **Occupancy Modeling Summary**:
  - Percent **FOREST** was **positively** related to black bear occurrence. Sites with < 50% forest cover had <10% chance of being occupied by a black bear.
  - Percent **DEVELOPED** was **negatively** related to black bear occurrence. Sites with >15% development had < 10% chance of being occupied by a black bear.
  - As Vermont continues to develop, the probability that a black bear will occur at a site will decrease.





Results

Probability of occurrence of black bear in Vermont



- **Map**: Predicted probability of black bear occurrence based on model-averaging of 95% model confidence set selected from entire black bear model set. Circles indicate sites where black bears were detected, and crosses where they were not detected, during surveys conducted in May-August of 2003-2004.

- Details of mapping analysis are provided in Long, R. 2006. Ph.D. Dissertation; University of Vermont, Burlington, Vermont. http://www.uvm.edu/envnr/vtcfwru/Current_Projects/biodiversity.htm

Question

Given that black bears respond negatively to development, how will future population growth and associated conversion of natural land to “development” affect the distribution of black bears?

Methods

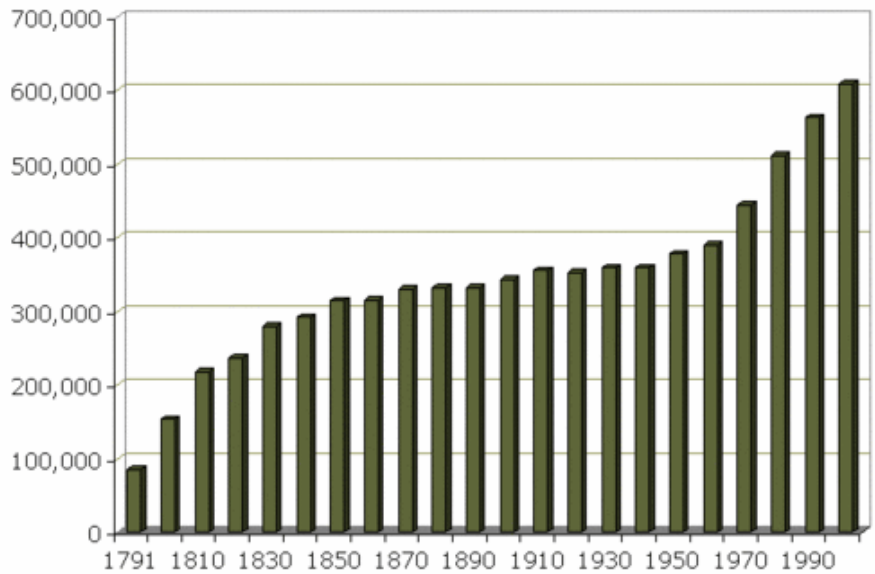
Obtain Vermont Population and Human Housing Density Statistics

- Recent analysis of growth patterns in Vermont from Smart Growth Vermont (http://www.smartgrowthvermont.org/).
- Current human housing density (year 2000) and projected human housing density (year 2020) from David Theobald, Colorado State University; report to Trust for Public Lands (http://www.nrel.colostate.edu/~davet/)
- Key reference: Theobald, D.M. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. *Ecology and Society* 10(1): 32. [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art32/.

Results

Recent Changes in Population and Housing Density in Vermont

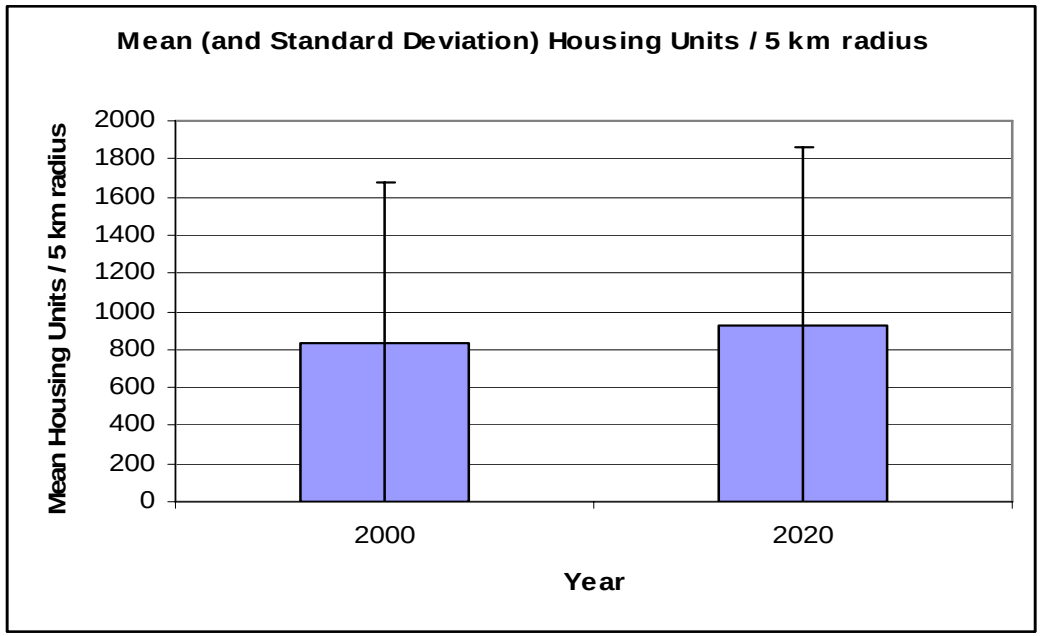
- Human density varies across Vermont from 3.7 people per km^2 (northeastern Essex County) to 91 people per km^2 (Chittenden County; with 24% of the state's population) (U.S. Census Bureau 2005).
- Although still primarily rural, Vermont has experienced at least 10% growth per decade since the 1960's (U.S. Census Bureau 2005).
- A study by the Vermont Forum on Sprawl (1999) indicates the rate of land development is ~ 260% greater than the rate of population growth. About 40% of that development occurred on farmlands, while much of the remaining development is occurring in forestlands.
- Between 1982 and 1992, the fastest growing type of development was a category known as "small urban built up" -- small, unconnected blocks of land that develop within a matrix of less developed land. This pattern is a particularly effective facilitator of wildlife habitat fragmentation.



Results

Projected Changes in Vermont Housing Density; 2000-2020.

- Based on 200 grid sampling points across Vermont and housing projections from David Theobald, Colorado State University.
- Housing units were projected to grow, on average, by 12% compared to baseline 2000 data at each site.
- Large standard deviations reflect broad range in housing units within 5 km of a sampling point, from 0 housing units to >20,000 housing units.
- Number of houses within 5 km of a sampling point is positively correlated with developed land cover classes, and negatively correlated with forested land cover classes.

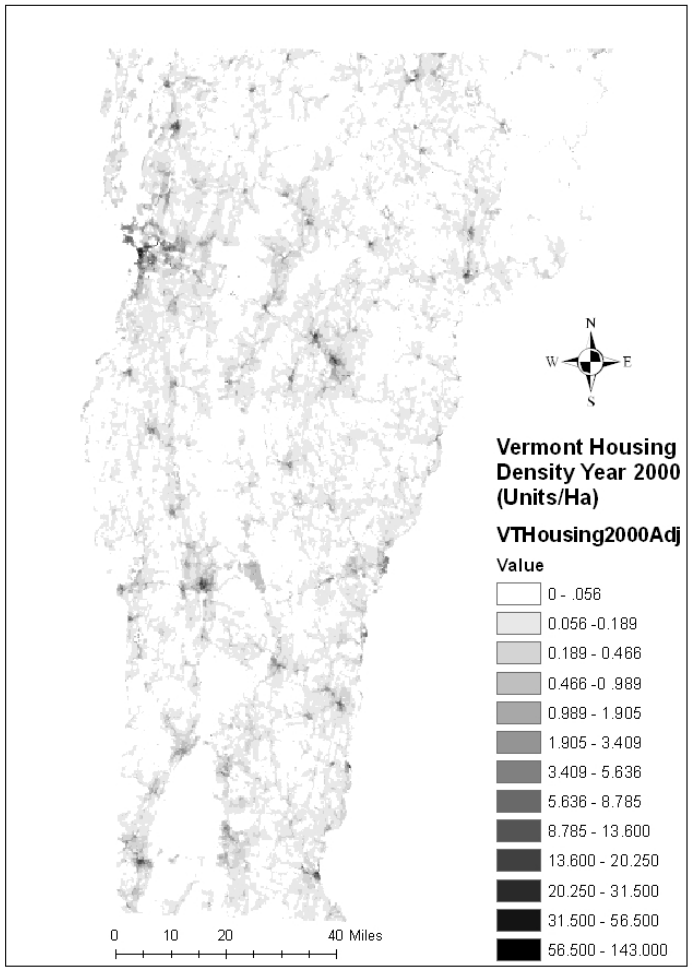


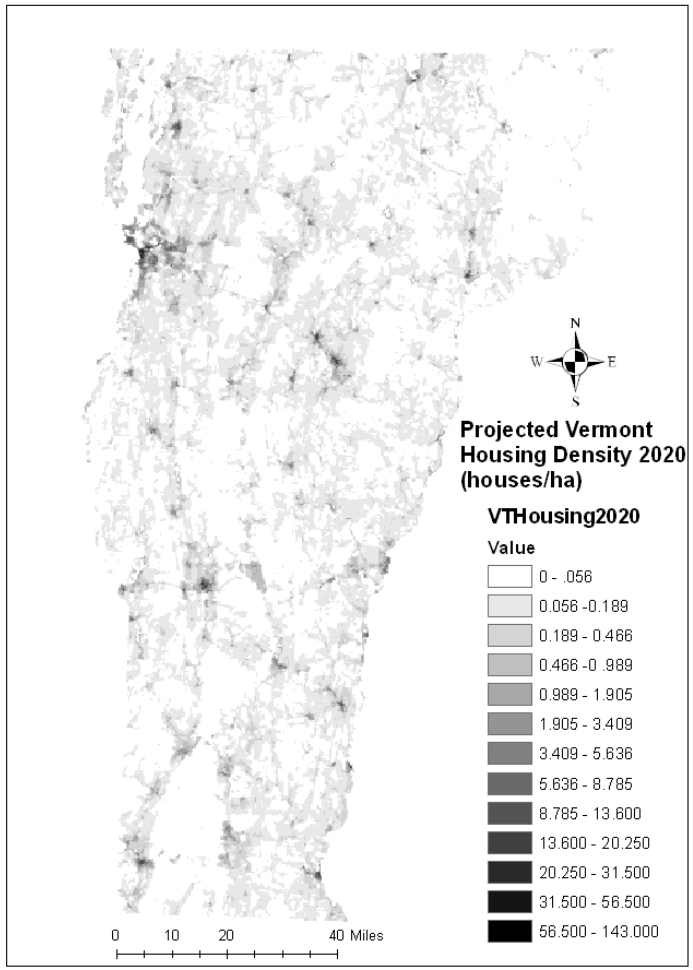
Pearson Correlation Coefficients, N = 200
Prob > |r| under H0: Rho=0

	HOUSES	Farm	Forest	Developed	Wetland
HOUSES	1				
Farm	0.13085 0.0648	1			
Forest	-0.35293 <.0001	-0.84235 <.0001	1		
Developed	0.93863 <.0001	0.28019 <.0001	-0.47806 <.0001	1	
Wetland	0.06823 0.337	0.28497 <.0001	-0.5441 <.0001	0.13418 0.0582	1

Results

Human Housing Units (2000; left map) and Projected Human Housing Units (2020; right map). Pixel size = 1 hectare.





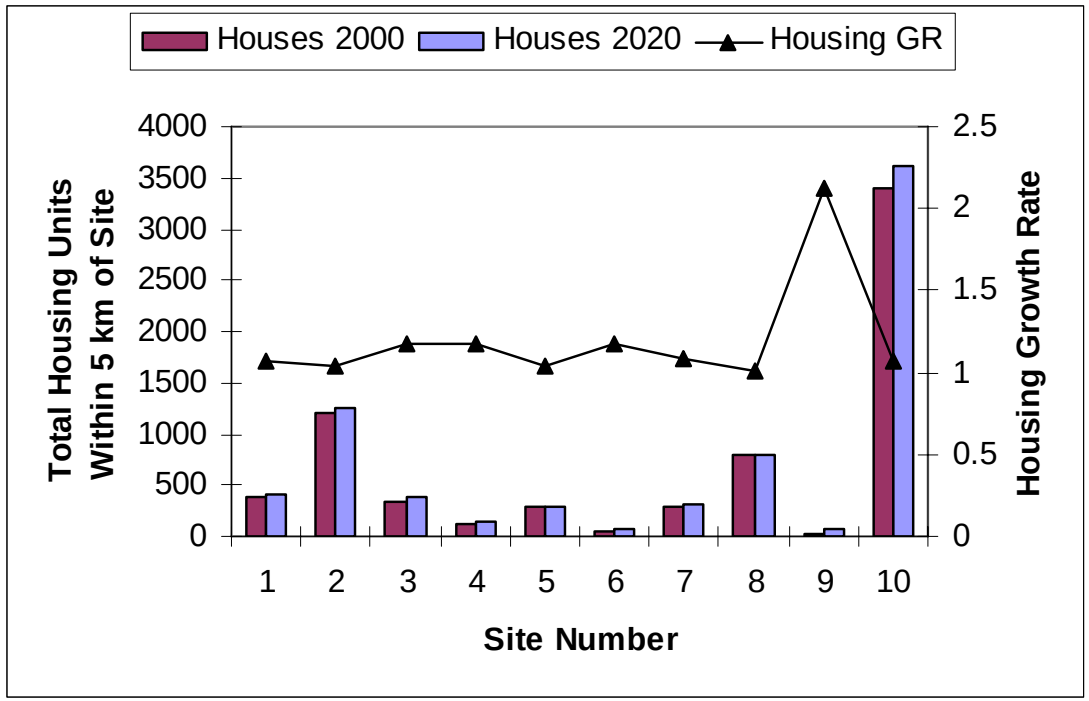
To understand how changes in human housing density will affect black bear distribution, we need to complete four tasks:

1. Determine human housing units and housing growth rates for each of the 168 black bear study sites.
2. Document statistical relationship between human housing units within 5 km of a site and the percent developed land cover classes within 5 km of a site.
3. Use the statistical relationship to predict change in development and forest cover at each black bear survey site based on changes in human housing units.
4. Determine how the probability that a site will be occupied by black bears will change as a result.

Results

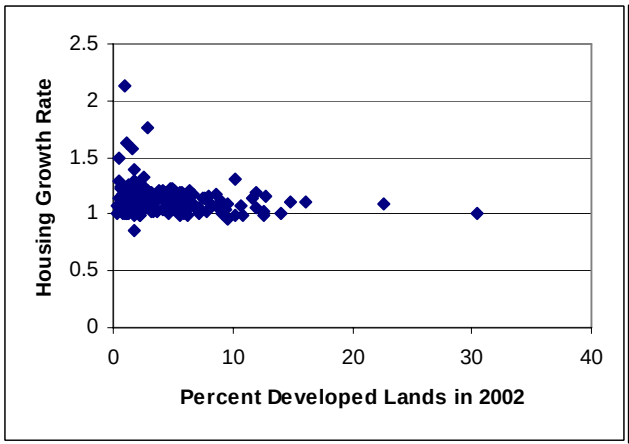
Task 1. Determine changes in human housing units from 2000 to 2020, and determine housing growth rates for each black bear study site.

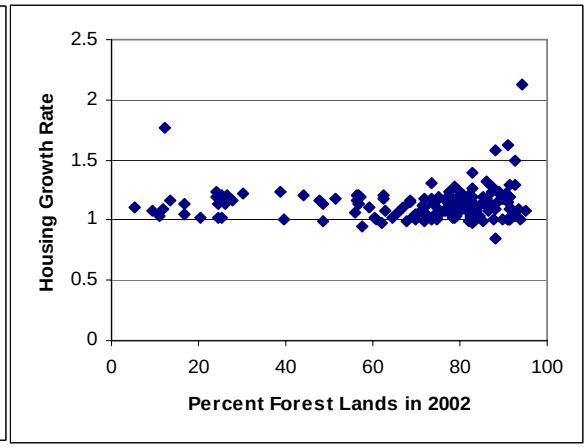
- The total increase in housing units within 5 km of the black bear study sites was projected to be 12,107 units.
- The total number of housing units in 2000 and the projected number of housing units in 2020 for 10 of the 168 sites are shown in the graph to the right.
- Housing growth rate (triangles) was calculated as Housing Units 2020/Housing Units 2000. A growth rate of 1.0 indicates no change in housing units.
- The average housing growth rate across all black bear sampling points was 1.13, or 13% growth over baseline 2000 values.

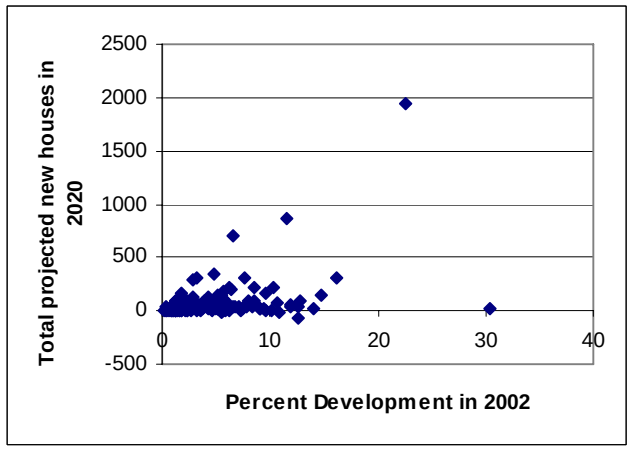


Results

Task 1. Determine changes in human housing units from 2000 to 2020, and determine housing growth rates for each black bear study site.





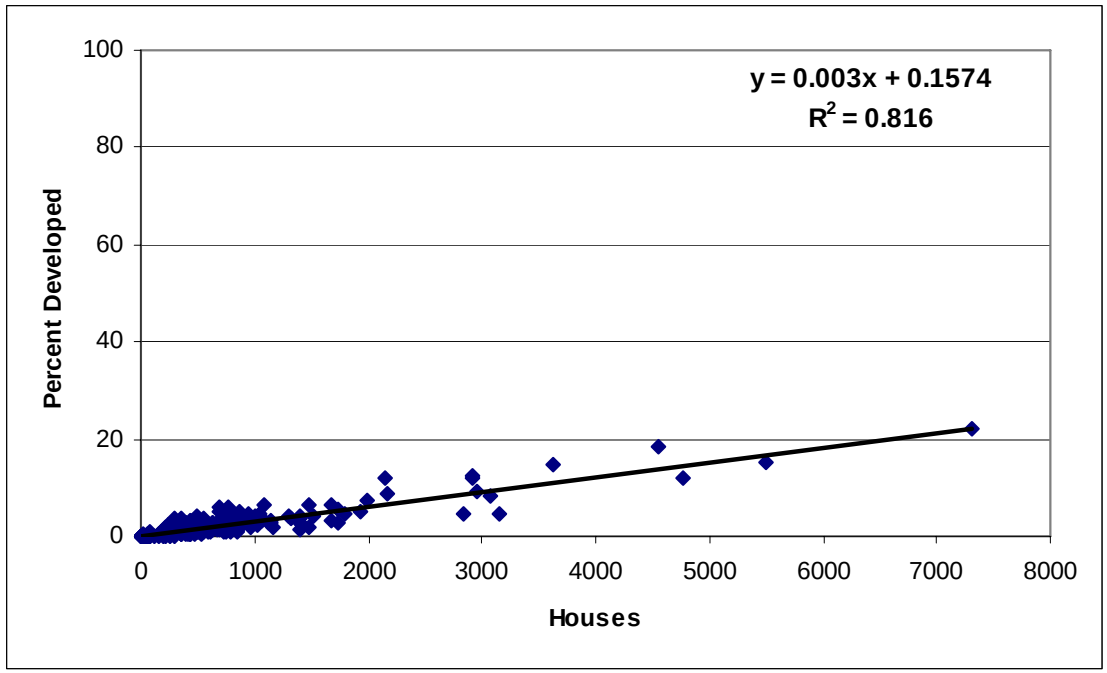


- **Left graph**. Largest housing growth rate are projected to occur in sites with low development in 2002, potentially indicating sprawling development.
- **Middle graph**. Largest housing growth rates are projected to occur in sites with high forest cover in 2002.
- **Right graph**. Total projected increases in housing units are clustered in sites with less than 15% development. Sites in this range are particularly vulnerable to decreases in black bear occurrence because of the abrupt decline in probability of occurrence when landscapes contain < 15% development.

Results

Task 2. Document statistical relationship between human housing units within 5 km of a site and the percent developed land cover classes within 5 km of a site.

- Strong, positive relationship between total housing units within 5 km of a sample point and percent developed land cover.
- Slope of 0.003 indicates that for an increase in one housing unit, there is a 0.003 percent increase in development.
- This makes sense because housing is a major "development" category.



Task 3. Use the statistical relationship to predict change in percent development and forest cover at each black bear survey site based on changes in human housing units. Two future scenarios will be run:

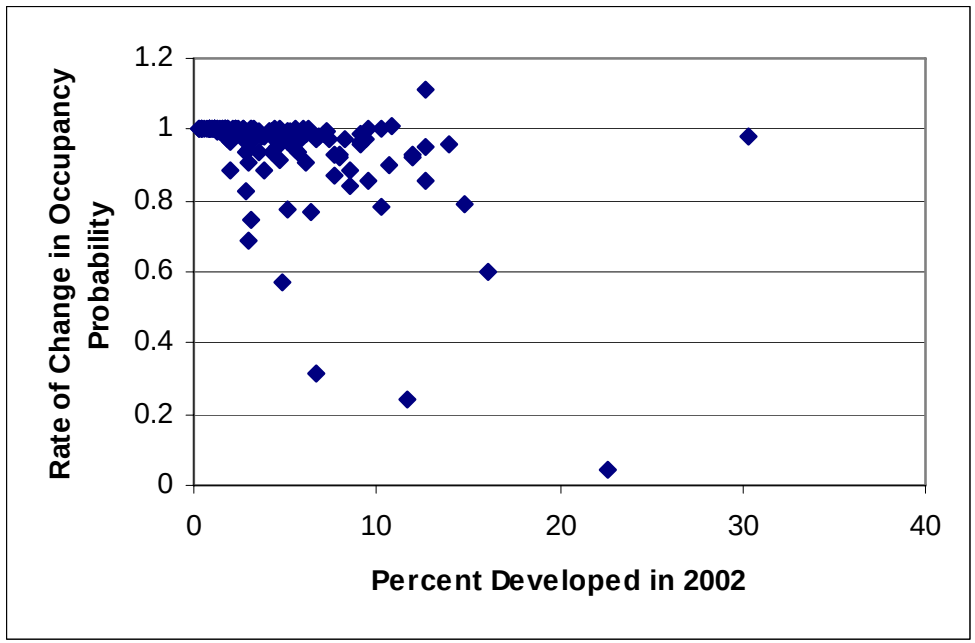
1. Percent development increases as human houses increases according to the equation y = 0.003 * change in housing units from 2000 to 2010 + housing units 2000. This development will occur on forested lands. The key assumption of this scenario is the growth patterns in 2020 follow same pattern of housing and development as documented in 2000. This is the “traditional growth” scenario.

2. Percent development increases at a rate of 240% times the rate of human housing growth. Half of this development will occur on forested lands. This is the “sprawl” scenario.

Results

Task 4. Projected Changes in Black Bear Occurrence 2020; Scenario 1: Traditional Growth

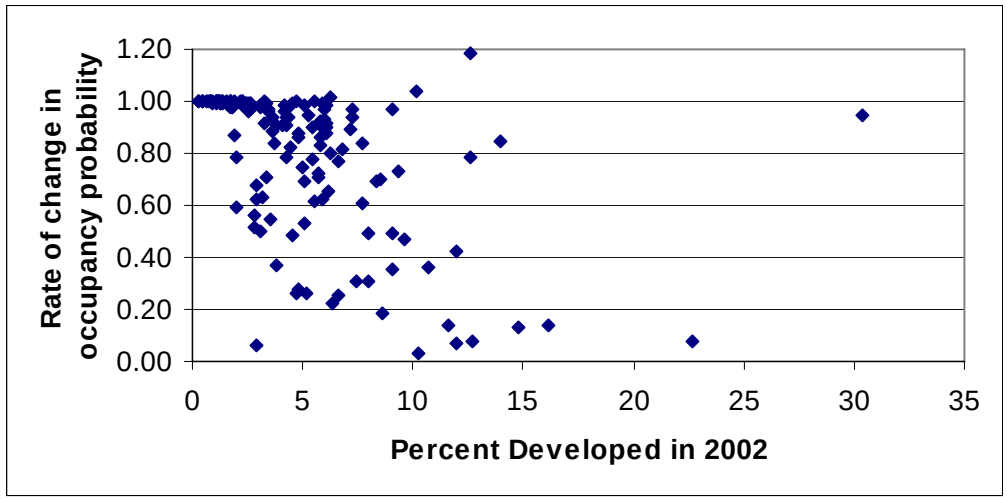
- Development increases as human houses increases according to the equation y = 0.003 * change in housing units from 2000 to 2020.
- Under this scenario, the raw percentage of development within 5 km of a study site declined by only 0.22%, on average.
- Under this scenario, the percentage of "developed" classes at a site grew between -1% and 32% over baseline 2000 levels.
- On average across all sites, developed land classes grew 5.2% over baseline 2000 levels.
- "Rates of Change" in the probability of occupancy were measured as probability of occupancy at a site in 2020 / probability of occupancy at a site in 2000. A rate of change of 0.8, for example, suggests a 20% decline from baseline values.
- On average, there is projected to be a 5% decline in the probability that a site will be occupied by black bear compared to baseline measures in 2000.
- A graph of rates of change for each site against its percent development suggests that sites with more than ~3% development in 2000 will decline the most.



Results

Task 4. Projected Changes in Black Bear Occurrence 2020; Scenario 2: Sprawling Growth

- In the sprawl scenario, projected development increases at a rate of 260 % times the rate of human housing growth, a pattern of recent growth patterns in Vermont. Half of this development will occur in forests.
- Under this scenario, the raw percentage of development within 5 km of a study site declined by 1.3%, on average.
- On average across all sites, developed land classes grew 35% over baseline 2000 levels.
- "Rates of Change" in probability of occupancy were measured as probability of occupancy at a site in 2020 / probability of occupancy at a site in 2000. A rate of change of 0.8, for example, indicates a 20% decline in occupancy probability from 2000 baseline values.
- On average, there is projected to be a 18% decline in the probability that a site will be occupied by black bear compared to baseline measures in 2000. The median decline was 5%.
- A graph of growth rates for each site against its percent development suggests that sites with more than 3% development in 2000 will decline the most.



Implications and Applications in the Northern Forest region

- How will Vermont develop? Sprawl or compact towns?
- Black bears face a slippery downward slope in terms of probability of occupancy, especially in landscapes that are currently < 15% developed.
- However, future development is projected to occur in sites with under 10% development in 2000. For conservation of this species, it would be better to shift this development to areas with > 30% development because this won't change the probability of occurrence (bears won't be there anyway).

Implications and Applications in the Northern Forest region

Important Caveats

- Projecting development patterns is very complex and results are contingent upon whether the underlying assumptions are met.
- Understanding factors that shape the probability of black bear occurrence is also complex. The probability that a wild species will occur at any site is shaped by many additional factors besides land cover pattern (e.g., black bear occurrence is shaped by beech nut production, climate, population dynamics).
- Conservation of biological diversity requires protection of a full range of species, not just forest specialists such as black bears.

Future directions

- Conduct similar analyses on other native species.
- Include assessment of how local-scale forest structure and forestry practices affect probability of occurrence.
- Identify how projected development will affect core habitat, wildlife corridors, and landscape fragmentation.
- Long term monitoring of these sites on a 5 year basis for understanding links between biodiversity, land change, climate change, and changes in ecosystem services.
- Theoretical tests of umbrella species, keystone species, and indicator species concepts and their suitability for large-scale conservation.

List of Products

Peer Reviewed Publications

- **Peer Reviewed Publications**
  - Long, R. A., T. M. Donovan, P. MacKay, J. S. Buzas, and W. J. Zielinski. 2007. Effectiveness of scat detection dogs for detecting forest carnivores. Journal of Wildlife Management 71:2007–2017.
  - Long, R. A., T. M. Donovan, P. MacKay, J. S. Buzas, and W. J. Zielinski. 2007. Comparing scat detection dogs, cameras, and hair snares for surveyin carnivores. Journal of Wildlife Management 71:2018–2025.
  - Manaras, K.W., W. S. Keeton, T. M. Donovan, and B. Mitchell. Stand-level forest structure in avian habitat: scale dependencies in predicting occurrences in a heterogeneous forest. Forest Science: *in press*.
  - Donovan, T., and J. Hines. 2007. Exercises in occupancy modeling and estimation. Electronic book. http://www.uvm.edu/envnr/vtcfwru/spreadsheets/occupancy/occupancy.htm
- **Manuscripts In review**:
  - K. Rinehart, T. Donovan, B. Mitchell, R. Long. Factors influencing occupancy patterns of Eastern Newts across Vermont. Biological Conservation: *In review*.
  - Mitchell, Brian R., and Therese M. Donovan. Mob mentality: the effect of a mobbing tape on detections during point count surveys. Open Ornithology Journal: *In review*.
- **Manuscripts In Preparation:**
  - Long, R. A., T. M. Donovan, P. MacKay, J. S. Buzas, W. J. Zielinski, and K. Royar. Predicting carnivore occurrence using data collected with multiple, noninvasive methods. *In preparation*.
  - Mitchell, Brian. R., and Therese M. Donovan. Goodness of fit testing for Huggins closed-capture removal models. Journal of Agricultural, Biological, and Environmental Statistics. *In preparation*.
  - Aboulezz, H. G., A. Borowske, and T. M. Donovan. Predicting impacts of land use change on ovenbird distribution in Vermont. Auk. *In preparation.*
  - McGrew, J., T. M. Donovan, H. Aboulezz, A. Borowske, W.S. Schwenk, D. Theobald, and R. Mickey. Predicting impacts of land use change on natural and developed land classes in Vermont: implications for wildlife conservation. Journal of Conservation Planning. *In preparation.*
  - T. M. Donovan, J. McGrew , R. A. Long,, and D. Theobald. Predicting impacts of land use change on black bear distribution in Vermont. Conservation Biology. *In preparation.*

List of Products

Theses and Dissertations

- Long, Robert A. 2006. Developing predictive occurrence models for carnivores in Vermont using data collected with multiple noninvasive methods. Ph.D. Dissertation. The University of Vermont, Burlington, VT.
- Rinehart, Kurt. 2006. Factors affecting occupancy patterns of Eastern Newts across Vermont. M.S. Thesis. The University of Vermont, Burlington, VT.
- Manaras, Katherine W. 2006. Forest structure at multiple scales: Structural classification and predicting species occurrence in Northern hardwood-conifer forests. M.S. Thesis. The University of Vermont, Burlington, Vermont.

Website Materials

- All publications can be downloaded at http://www.uvm.edu/envnr/vtcfwru/Current_Projects/biodiversity.htm
- We are currently developing geodatabases that contain downloadable GIS maps.
- An electronic book has been produced to teach users how to use occupancy statistical methods for modeling wildlife probability of occurrence. The entire book can be downloaded at: http://www.uvm.edu/envnr/vtcfwru/spreadsheets/occupancy/occupancy.htm

List of Products

Conference Presentations

- Long, R.A., T.M. Donovan, P. MacKay, W.J. Zielinski, and J.S. Buzas. 2006. Predicting carnivore occurrence with data collected via multiple, noninvasive methods. Defenders of Wildlife's Carnivores 2006: Habitats, challenges, and opportunities. St. Petersburg, Florida. 14-17 November. (Paper)
- Long, R.A., T.M. Donovan, P. MacKay, W.J. Zielinski, and J.S. Buzas. 2006. Predicting carnivore occurrence with data collected via multiple, noninvasive methods. 2006 Northeast Fish and Wildlife Conference. Burlington, Vermont. 23-26 April. (Paper)
- Long, R.A., T.M. Donovan, P. MacKay, W.J. Zielinski, and J.S. Buzas. 2006. A comparison of noninvasive survey techniques: forest carnivores in Vermont. 2006 Annual Conference of the Western Section of the Wildlife Society Pre-conference Symposium: Fisher and Marten in California: Moving Science and Management Forward. Sacramento, California. 8-10 February. (Poster)
- Long, R.A., T.M. Donovan, P. MacKay, W.J. Zielinski, and J.S. Buzas. 2005. Comparing the effectiveness of scat detector dogs, remote cameras, and hair snares for detecting forest carnivores. The Wildlife Society 12th Annual Conference, Madison, Wisconsin. 25-29 September. (Paper)
- Long, R.A., T.M. Donovan, P. MacKay, W.J. Zielinski, and J.S. Buzas. 2004. Detecting wide-ranging carnivores in the Northeast: A comparison of three noninvasive methods. Defenders of Wildlife's Carnivores 2004: Expanding partnerships in carnivore conservation. A conference on carnivore biology and conservation. Santa Fe, New Mexico. 14-17 November. (Paper)
- Long, R.A., T.M. Donovan, P. MacKay, W.J. Zielinski, and J.S. Buzas. 2002. Scat-sniffing dogs as a tool for studying forest carnivores in Vermont. Defenders of Wildlife's Carnivores 2002: From the mountains to the sea. A conference on carnivore biology and conservation. Monterey, California. 17-20 November. (Paper)
- Long, R.A.. 2002. Moderator: Methodologies for Carnivore Research Symposium. Carnivores 2002: From the mountains to the sea. A conference on carnivore biology and conservation, Monterey, California. 17-20 November. (Paper)
- Manaras, K. W., W. S. Keeton, T. M. Donovan, and B. Mitchell. 2005. Forest structure and avian habitat: scale dependences in occurrence prediction. The Ecological Society of America 90th Annual Meeting, Montreal, Quebec, CA. 7-12 August, 2005.
- Mitchell, B. R., and T. M. Donovan. 2005. Factors influencing the probability of detecting Vermont songbirds during point counts. The Ecological Society of America 90th Annual Meeting, Montreal, Quebec, CA. 7-12 August, 2005.
- Mitchell, B. R., and T. M. Donovan. 2005. Factors influencing the probability of detecting Vermont songbirds during point counts. The Wildlife Society Annual Meeting, Madison, WI. 25-29 September, 2005.

Leveraged Grants

- Nature Conservancy. Biodiversity Surveys in the Southern Lake Champlain Ecoregion ; $20,000.
- Jon C. and Catherine Harvey Charitable Foundation. Noninvasive evaluation of the effects of disturbance and landscape pattern on North American forest carnivores; $28,000
- Vermont Fish and Wildlife Department. Effects of habitat fragmentation on carnivore distribution and fitness indicators in Vermont forests; $21, 680
- U.S. Geological Survey. A noninvasive evaluation of physiological stress and habitat use of northeastern carnivores; $20,000.
- Sweet Water Trust; $18,000.
- U.S. Forest Service; $10,000.
- University of Vermont contributions to the work of Brian Mitchell, Kurt Rinehart, and Katie Maneras.