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Representational Analyses of Conservation Lands in Maine

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REPRESENTATIONAL ANALYSES OF CONSERVATION LANDS IN MAINE

By

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An Abstract of the Thesis Presented
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The three studies reported here (i.e., statewide, southern Maine, and state and federal wildlife areas) identify what areas should be conserved to represent the natural diversity of Maine. Geographic Information System (GIS) technology was used to conduct the analyses comparing the distribution of abiotic and biotic variables representing natural diversity on and off conservation lands. In the statewide analysis, 10 environmental variables were compared on and off conservation lands using ArcGrid with a cell resolution of 1.86 x 1.86 km. The areas found to contain variables that were under-represented were combined to identify and map regions with under-represented characteristics. The mean number of under-represented variables for each major biophysical region in Maine was calculated with southern Maine being in greatest need of more conservation lands. The highest degree of under-representation was in low elevation areas and lower portions of large river valleys. When abiotic variables, which are more permanent to the landscape, were weighted higher than biotic, the same results as above were found.

To determine locations of potential new conservation lands in southern Maine, I analyzed the representation of seven environmental variables on conservation lands in

southern Maine with a cell resolution of 94.6 x 94.6 m. Only four variables were substantially under-represented including 401 – 450 m elevation, 4 – 7 degrees of slope, shoreline and mudflats, and early successional and crop cover types. The distance from these highly under-represented areas to areas with high road density was measured and mapped as an indicator of their vulnerability to development.

The contribution of Wildlife Management Areas (WMA's) and National Wildlife Refuges (NWR's) were analyzed to evaluate their contribution to the conservation of Maine's wildlife and natural diversity. Earlier management objectives for these agencies focused on acquisition of game (e.g., waterfowl) and endangered species habitats. Management emphasis has broadened recently to include conservation of ecosystems and all wildlife species, therefore, it is important to assess whether NWR's and WMA's accomplish these new, broader goals. Geographic datasets including topography, vegetation cover, and terrestrial vertebrate richness were compared on and off WMA's and NWR's using ArcGrid with a cell resolution of 94.6 x 94.6 m for each major biophysical region in Maine. Out of 270 terrestrial vertebrate species predicted to occur in Maine, 219 were predicted to occur on WMA's and 223 on NWR's. Wetland and open water vertebrate species, wetland vegetation types, and low elevation areas were over-represented in the state, while most upland vegetation types were under-represented by WMA's and NWR's. These results suggest that WMA's and NWR's should acquire additional mid-elevation and upland areas, assuming a goal of land conservation that is representative of the state's natural diversity.

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PREFACE

The concept of a network of conservation lands encompassing representative samples of the natural ecosystems in the world is not new. In 1890, F. von Mueller addressed the Australian Association for the Advancement of Science and called for every nation to reserve choice areas for maintenance of the native vegetation and wildlife (as cited in Scott 1999). Calls for preserving a representative sample of biodiversity on conservation lands continue (e.g., Dasman 1972, Bedward *et al.* 1992). Purchasing conservation lands because they are easy to obtain or less expensive cannot be an option (Pressey *et al.* 1993). In Maine, there has been no attempt to assess how conservation lands are doing at preserving the range of natural diversity that exists statewide (i.e., conserving a representative sample).

A representational analysis identifies the range of natural variation defined in a geographic area, and what has and has not been conserved and thus depends on known elements of diversity and their mapped occurrences (Scott 1999). There have been recent attempts to study the representation of diversity on public lands and reserves for large areas such as entire nations. Crumpacker *et al.* (1988) assessed the status of Kuchler's (1964) vegetation types on federal and Indian lands in the United States and found at least 33 of the 135 vegetation types were inadequately represented. Hunter and Yonzon (1993) assessed the representation of reserves in Nepal and found as altitude increases, species richness and human population densities gradually decrease and the distribution of park lands is more abundant in areas of higher altitude. In a study of protected areas in Sweden, Nilsson and Gőtmark (1992) found a large area of alpine landscapes represented but only a small area of river landscapes.

Other studies have been conducted for a state or an ecoregion in the U.S.A. In the intermountain semi-desert ecoregion, Stoms *et al.* (1998) found 28 out of 44 mapped vegetation types had < 10% of their area in conservation. In the southwest ecoregion of California, 19 out of 62 vegetation communities had < 10% of their area in conservation and were considered at risk (Davis *et al.* 1998). In Utah and Idaho, 30 of 36 (Edwards *et al.* 1997), and 33 of 71 (Caicco *et al.* 1995), respectively, of the vegetation types analyzed failed to have 10% of their area in reserves, parks or wilderness areas. The Brundtland Commission (Brundtland 1987) suggested 12% (and other authors suggest 25 – 75% [Noss and Cooperrider 1994]) of the land are needed to meet conservation goals.

This thesis addresses three issues related to the representation of public and private conservation lands in Maine. Chapter 1 assumes that Maine will double the amount of public and private conservation lands by 2020 (Maine State Planning Office 1997), and addresses the issues of (1) the kinds of areas that should be conserved to more fully represent Maine's natural variability, and (2) the general locations of these areas in the state. Chapter 2 takes the highest priority region of Maine identified in Chapter 1 and looks at the issues of what, where, and how much to conserve. Chapter 1 used an analysis resolution of 1.86 x 1.86 km whereas in Chapter 2 a 94.6 x 94.6 m cell size was used , allowing me to assess the effects of data resolution on the representation analyses. Chapter 3 asks the more restricted question: what do inland (i.e., non-coastal islands) Wildlife Management Area's, managed by the Maine Department of Inland Fisheries and Wildlife, and National Wildlife Refuge's, managed by the U.S. Fish and Wildlife Service, contribute to the conservation of the state's natural variability, giving special emphasis to Maine's wild fauna?

LITERATURE CITED

Brundtland, G.H.(chairperson). 1987. Our Common Future: World commission on environment and development. Oxford University Press, New York, NY, 400 pp.

Caicco, S.L., J.M. Scott, B. Butterfield, and B. Csuti. 1995. A Gap Analysis of the management status of the vegetation of Idaho (U.S.A.). *Conservation Biology* 9:498-511.

Crumpacker, D.W., S.W. Hodge, D.F. Friedley, and W.P. Gregg, Jr. 1988. A preliminary assessment of the status of major terrestrial and wetland ecosystems in the United States. *Conservation Biology* 2:103-115.

Dasmann, R.F. 1972. Towards a system for classifying natural regions of the world and their representation by national parks and reserves. *Biological Conservation* 4:247-255.

Davis, F.W., D.M. Storms, A.D. Hollander, K.A. Thomas, P.A. Stine, D. Odion, M.I. Borchert, J.H. Thorne, M.V. Gray, R.E. Walker, K. Warner, and J. Graae. 1998. The California Gap Analysis--Final Report. University of California, Santa Barbara, CA. [http://www.biogeog.ucsb.edu/projects/gap/gap_rep.html]

Edwards, T.C., Jr., C.G. Homer, S.D. Bassett, A. Falconer, R.D. Ramsey, and D.W. Wright. 1995. Utah Gap Analysis: an environmental information system. Technical report 95-1. Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, Utah. Unpaged.

Hunter, M.L., Jr., and P. Yonzon. 1993. Altitudinal distributions of birds, mammals, people, forests, and parks in Nepal. *Conservation Biology* 7:420-423.

Maine State Planning Office. 1997. Final Report and Recommendations of the Land Acquisition Priorities Advisory Committee. Submitted to Governor Angus S. King, Jr., November, 1997. 22 pp.

Nilsson, C., and F. Götmark. 1992. Protected areas in Sweden: Is natural variety adequately represented? *Conservation Biology* 6:232-242.

Noss, R.F., and A.Y. Cooperider. 1994. Saving natures legacy: protecting and restoring biodiversity. Island Press, Washington, D.C., 416 pp.

Pressey, R.L., C.J. Humphries, C.R. Margules, R.I. Vane-Wright, and P.H. Williams. 1993. Beyond opportunism: key principles for systematic reserve selection. *Trends in Ecology and Evolution* 8:124-128.

Scott, J.M. 1999. A representative biological reserve system for the United States? *Society for Conservation Biology Newsletter* 6:1-9.

Scott, J.M., F.W. Davis, R.G. McGhie, R.G. Wright, C. Groves, and J. Estes. 2001. Nature Reserves: Do they capture the full range of America's Biological Diversity? *Ecological Applications* 11(4):999-1007.

Stoms, D.M., F.W. Davis, K.L. Driese, K.M. Cassidy, and M.P. Murray. 1998. Gap Analysis of the vegetation of the intermountain semi-arid desert ecoregion. *Great Basin Naturalist* 58: 199-216.

CHAPTER 1

A REPRESENTATIONAL ANALYSIS OF LARGE CONSERVATION LANDS IN MAINE

INTRODUCTION

Worldwide, species are going extinct at least 100 times faster than natural background rates (Pimm and Lawton 1998). If appropriate conservation measures are not taken soon, at least one quarter, but most likely more, will be lost forever (Brundtland 1987). There are estimates that 1.5% of the Earth's surface (World Resources Institute 1992), and 5% of the land in the coterminous United States (Scott *et al.* 2001), has been set aside in nature preserves or protected areas. It has been predicted that "... if human activities destroy or greatly modify the remaining 95% of the land, only half the planet's species would survive in the protected 5%, the other half would go extinct" (Pimm and Lawton 1998). These predictions on the loss of the world's biological diversity (biodiversity), as well as many others, are leading to a reappraisal of conservation's goals and tactics (Soulé 1991).

Strategies for the location, design, and maintenance of conservation lands are some of the main tools being used for saving biological diversity (Davis *et al.* 1990, Leader-Williams *et al.* 1990, World Resources Institute 1992). The need for a network of reserves that is representative of the world's ecosystems has become a high-priority for many agencies and governments (Bedward *et al.*, 1992). Most of the lands set aside to date as ecological reserves are not representative of the natural variation of ecosystems (Scott 1999). A consensus of professional opinion suggests that the total extent of protected areas needs to be tripled, at least, in order to facilitate a representative sample of the Earth's ecosystems (Brundtland 1987).

The term representative, as used here, describes a network of conservation lands or reserves that portray examples of all the natural features in a region, defined by species or units such as vegetation types or ecosystems (Pressey 1992). A reserve system that is representative of the natural range of variation has the greatest chance of fulfilling its critical role in conserving biodiversity (Pressey *et al.* 1993, Brundtland 1987). Biodiversity has been defined as "... the diversity of life in all its forms, and at all levels of organization" (Hunter 1996). Uncoordinated and unplanned decisions may seriously compromise the reserve system's effectiveness toward that goal (Bedward *et al.* 1992, Pressey and Taffs [In Prep.], Pressey 1990). Two main disadvantages to *ad hoc* planning of conservation lands are that: 1) species, communities, or ecosystems needing protection may be left without it; and 2) it can make the goal of representing regional diversity more expensive in the long run and reduce the chance of protecting many elements of biodiversity (Pressey 1994).

The above not withstanding, the selection of conservation lands worldwide still tends to be opportunistic and without any clear picture of regional conservation priorities (Ando *et al.* 1998, Pressey 1994). In many cases a reserve or conservation area is selected because it "is the easiest, politically and economically, to obtain and protect" (Pressey and Tully 1994). Conservation lands have also been obtained due to concerns over scenic and recreational values (Scott and Csuti 1997). Globally, the reserves we have are poorly allocated, with the larger ones (> 100,000 km^2) distributed throughout high mountains, tundra, and deserts, not areas particularly rich in species (Pimm and

Lawton 1998). Scott *et al.* (2001) discovered the nature reserves in the conterminous United States occurred most frequently on areas with high elevation and low soil productivity, while the largest number of species is found at lower elevations. Hunter and Yonzon (1993) found that in Nepal, conservation reserves were located on the highest and lowest elevations and did not parallel the distribution patterns of species richness. Rarely are conservation lands acquired with their representation of natural features as the overriding consideration (Pressey 1992).

An intelligent first step to achieving a representative reserve system is to assess the content of any existing reserves prior to acquisition (Pressey *et al.* 1993). This approach is dependent on two parameters: how well biodiversity can be measured and the availability of abiotic and biotic data for the purposes of conservation planning (Pressey 1992). It has been statistically demonstrated that the broad-scale distribution of woody plants is largely related to climate and geomorphology (McMahon 1990, Boone and Krohn 2000a,b, Nichols *et al.* 1998), and that the broad-scale distribution of terrestrial vertebrates is related to climate, geomorphology, and plants (Boone and Krohn 2000a,b, Nichols *et al.* 1998). Thus, it is possible to use measures of climate, geomorphology, woody plants, terrestrial vertebrates, and others as surrogate measures of the state's terrestrial biodiversity. The use of readily available surrogates of biodiversity to quantitatively compare reserves and all lands over extensive areas is an effective methodology (e.g., Hunter and Yonzon 1993, Scott and Csuti 1997, Wessels *et al.* 1999), and has been studied extensively in Australia (e.g., Margules 1989, Pressey 1990). If representation of biological diversity is a goal, a management strategy that ranks landscape patterns and regional biogeography higher than local concerns may be necessary (Noss 1983).

The paleoecological record shows the most modern plant communities in North America are temporary assemblages and that their distribution and abundance on the landscape shifted over time (Hunter *et al.* 1988). Thus, if a reserve network is selected based on data such as species distributions at one point in time, it may not continue to achieve its goal over the long term (Hunter *et al.* 1988, Margules *et al.* 1994). When planning for the location of nature reserves, the significant changes in climate expected to occur in the next century must be considered to ensure the long-term survival of organisms (Hunter *et al.* 1988). Paleoecological studies have also shown "diverse landscapes have supported diverse vegetation types over long periods during which climates have changed" (Hunter *et al.* 1988, 381). According to Nichols *et al.* (1998) , "the conservation of geomorphological heterogeneity is likely to be an efficient strategy for conserving both extant and potential diversity." Thus, this analysis places emphasis on the more permanent features (i.e., topography and climate) rather than the temporary features (i.e., vertebrate and plant distributions) on the landscape.

Land conservation efforts in the U.S.A. have been focused on the management of existing public lands, even though private lands cover more area and support many more wild species (Knight 1999). A major threat to our natural heritage is the continued conversion of private lands to more intensive land uses (Knight 1999). In Maine, about 1 million hectares (ha) (12% of the state's total ha) of private forestlands exchanged ownership in 1999 (Izakson 1999). These land transactions have allowed for opportunities to purchase some of these areas for conservation. However, the state of

Maine was unprepared for such purchases. This has led to an increased public awareness of the need for a new land acquisition bond. It has been projected that in Maine by the year 2050, there will be a loss of 3% of private timberlands, while the human population will increase by 16% and urban lands by 56%, mainly in counties in southern Maine (Plantinga *et al.* 1999).

Only some 5.3% (444,335 ha) of Maine is in public ownership (Krohn *et al.* 1999) and 1.3% (112,534 ha) is in private conservation ownership. In November 1987, a referendum for a $35 million bond was passed to acquire lands of statewide significance for recreation and conservation. With funds from the $35 million bond nearly depleted, the Land Acquisition Priorities Advisory Committee (LAPAC) was established to develop recommendations for what future land acquisition is needed in the state, and how the state should pay for it (Maine State Planning Office 1997). One of the land acquisition goals is to double public and private conservation ownership in Maine by the year 2020 (Maine State Planning Office 1997). Thus, for Maine, the question of how much land to put into public ownership (from 462,380 to 888,670 ha, Maine State Planning Office 1997) has been answered for the immediate future. What areas should be conserved and where are questions that still remain unanswered.

The purpose of this study was to identify, in a spatially explicit format, those areas in need of conservation at a statewide level. To date, there has been no comprehensive analysis to determine what role or contribution conservation lands plays in conserving the state's natural diversity. This analysis was based on the following three assumptions: (1) public conservation lands should represent the natural variation in the landscapes of Maine (Pressey 1994, Scott 1999), (2) large conservation lands are more valuable than smaller ones when assessing them at a statewide level (Wright and Tanimoto 1998), and (3) more emphasis should be placed on abiotic variables than biotic variables in a coarse-scale analysis (Hunter *et al.* 1988, National Research Council 1993, Nichols *et al.* 1998).

My objectives were as follows:

(1) Determine the distributions of major environmental (i.e., abiotic and biotic) variables across conservation and non-conservation lands in Maine, and aggregate the highly under-represented variables and to identify the areas most in need of additional conservation lands in the state.

(2) Rank the major biophysical regions of the state according to the extent the environmental variables were under-represented using a relative difference between conservation lands and non-conservation lands.

(3) Assess the sensitivity of the under-representation analysis (Objective 2 above) to the variables used and to the cutoff's used to define representation (i.e., threshold levels) using absolute versus relative differences.

STUDY AREA

My study area, Maine, is approximately 450 km north to south and 320 km east to west and covers more than 83,000 km^2, and stretches from 42° 58' to 47° 30' north latitude and 66° 56' to 71° 07' west longitude. Maine supports a variety of physical settings from the northeastern extreme of the Appalachian Mountain chain and Mount Katahdin to the rocky coastline, north to the forestlands, and downeast to the peatlands. The southern areas have elevations generally below 300 m above msl. There is a 50-100 km-wide band stretching east-west within the state, where many southern species reach their northern limit, and where a number of northern woody plant species reach their southern limit (McMahon 1990). A similar band of range limits of plant species runs north-south (McMahon 1990). These bands of increased species richness increase the diversity and complexity of ecosystems, which in-turn are associated with more vertebrate species to occupy the region (Boone and Krohn 2000a).

METHODS

Conservation Lands

The conservation lands in Maine are incorporated in the Conservation and Public Lands Database (CAPLD) (scale = 1:100,000) (Krohn and Kelly 1997), which includes over 120 individual landowning organizations distributed among federal, state, municipal, and private conservation agencies and organizations as of 1993. The database consists of over 1,092 parcels of land and an attribute database that characterizes each parcel by name, ownership, location, and size (Figure 1.1) (Krohn and Kelly 1997).

For this analysis, conservation lands are defined as those parcels in CAPLD as of 1997 that are private or public lands managed primarily for conservation purposes. Examples of included parcels are state parks, National Parks, National Wildlife Refuges (NWR), Wildlife Management Areas (WMA) and lands owned by the Maine Chapter of The Nature Conservancy (TNC). Examples of public parcels in CAPLD not included in this study are state historic sites, scenic areas, fish hatcheries, cemeteries, recreation parks, schools, and military lands. Due to the large size of the area, I digitized the

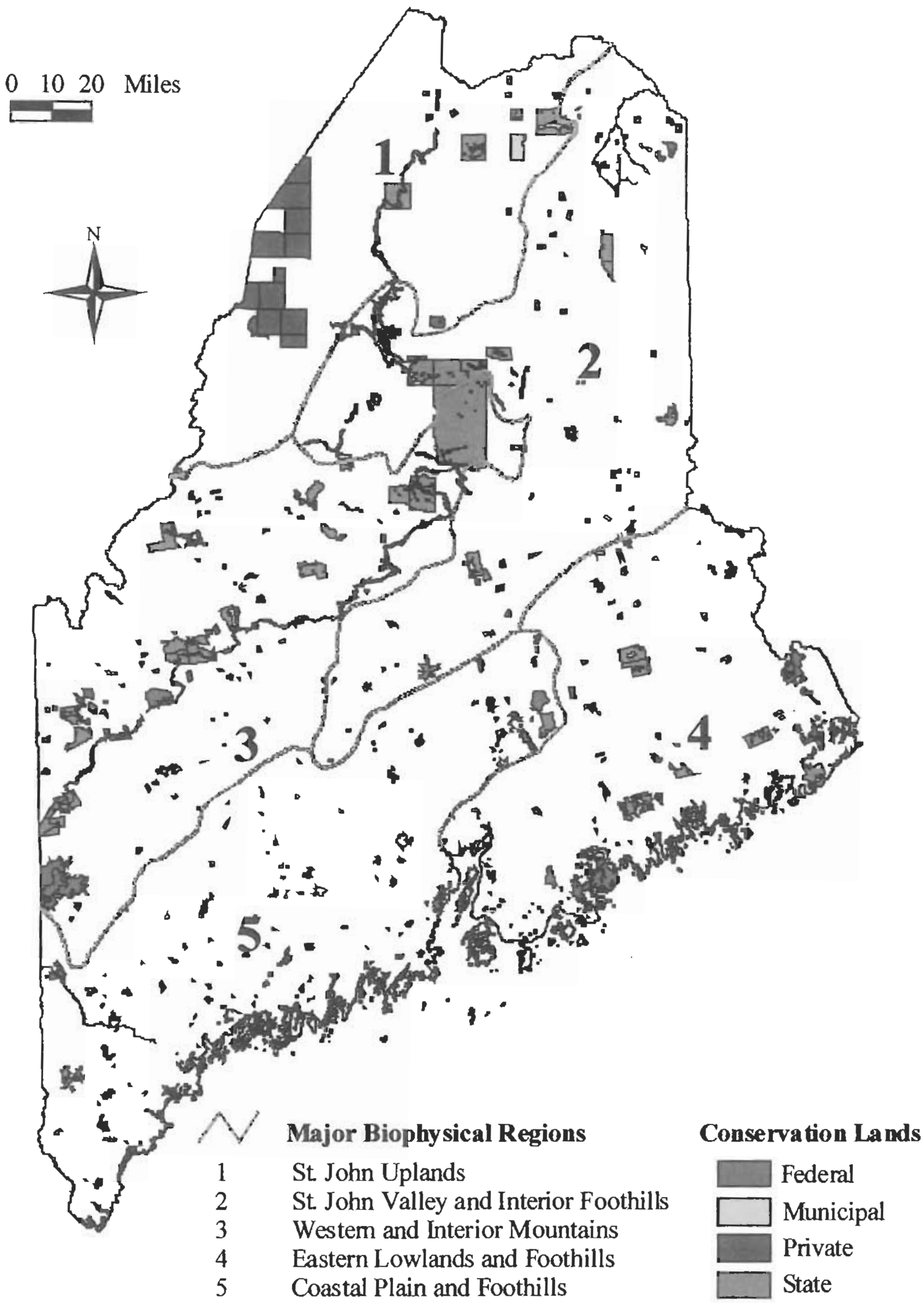


Figure 1.1. The location and ownership of conservation lands (excluding Native American lands) in Maine, 1993.

boundaries of the 74,867 ha parcel purchased by TNC in northwestern Maine in 1999 and added it to CAPLD.

With the exception of the 1999 land purchase by the Maine Chapter of TNC, there have not been any recent, large acquisitions of conservation lands. However, many small land parcels have been purchased since 1993, especially in coastal Maine, but these generally fall below the size threshold for this study (< 1.86 km^2, see below).

Environmental Variables

Eleven abiotic and biotic variables were analyzed, including topography, climate, hydrology, woody plants, and terrestrial vertebrates (Table 1.1). The variables I selected for analysis assumed that (1) nature reserves should be more strongly influenced by the physical environment (i.e. permanent features) versus dynamic biological communities (Hunter *et al.* 1988), and (2) climate and woody plants have been found to be correlated with vertebrate richness (e.g., Boone and Krohn 2000a).

For each of the analyses, the variables occurrence on conservation lands and non-conservation lands were determined using Geographic Information System (GIS) technology. The variables on conservation lands were compared to the variables on non-conservation lands on a grid basis, with a 1.86 x 1.86 km cell size, using ArcGrid, a cell-based module of ARC/INFO Version 7.2 (Windows NT) (Environmental Systems Research Institute, Redlands, California, USA; use of trade names does not imply endorsement). Each of the environmental variable grids were combined with the conservation lands grid and the non-conservation lands grid. The values for each variable were classified into groups, for instance, 0 – 100 m,-101 – 200 m, etc subdivided elevation. The number of cells in each group was counted; for example, there are 6,663 cells between 0 – 100 m elevation. The percent of each variable class in conservation lands and non-conservation lands was then calculated.

Table 1.1. Variables used in the statewide representational analysis of Maine. All data sets were analyzed at 1.86 x 1.86 km cell resolution.

Variables	Measure	Source Scale	Source
Abiotic			
Topography			
Elevation	m above msl	94.6 m	Digital Elevation
Slope	Angle degrees	94.6 m	Model (DEM), USGS[a]
Hydrography			
Streams	Distance to nearest (m)	1.86 km	(DLG), USGS
Rivers	Distance to nearest (m)	1.86 km	
Lakes	Distance to nearest (m)	1.86 km	
Ponds	Distance to nearest (m)	1.86 km	
Climate			
Heat accumulation	^{o}C days/year	1.86 km	Boone (1997)
Snowfall	cm/year	1.86 km	
Total precipitation	cm/year	1.86 km	
Biotic			
Woody plant richness	Number (n)	94.6 m	Boone (1996)
Terrestrial vertebrate richness	Number (n)	94.6 m	Boone and Krohn (1998a,b)

a – USGS = United States Geological Survey.

The relative difference between conservation and non-conservation lands was obtained by dividing the percent in conservation by the percent in non-conservation. Then each variable class was placed into one of three categories: (1) Highly Under-represented – a range of values for a variable that occurs more frequently on non-conservation than conservation lands (i.e., relative difference $\leq$ 0.5. Such areas are considered to be of high interest to conserve); (2) Under-represented – a range of values for a variable that occurs in roughly the same percent on both conservation and non-conservation lands (i.e., relative difference between 0.5 and 1.0), and (3) Well-represented – a range of values for a variable that occurs more frequently on conservation lands than non-conservation lands (i.e., relative difference $\geq$ 1.0).

A bar graph of each variable was created showing the percent of cells in conservation lands versus the percent of cells in non-conservation lands (See Figure 1.4A). A spatial representation of the bar graph was created by assigning different shades to the cells in the variable's grid that are highly under-represented, under-represented, and well represented.

Variables such as topography, climate, woody plant richness, and terrestrial vertebrate richness vary significantly across Maine (Boone and Krohn 2000a,b). Therefore, comparisons of conservation lands to non-conservation lands were more meaningful when limited to relatively homogeneous regions of the state. Krohn *et al.* (1999) quantitatively delineated the state of Maine into thirteen biophysical regions based on abiotic and biotic variables. For this analysis, I combined these into five major biophysical regions of roughly equal size (Figure 1.1), and compared the results of each variable's representation of conservation lands within each major biophysical region (Table 1.2).

Table 1.2. Percent and area (km^2) of conservation areas by primary ownership in each major biophysical region in Maine.

Conservation areas	Major biophysical regions [a]									
	St. John Upland		St. John Valley & Interior Foothills		Western & Interior Mountains		Eastern Lowland & Foothills		Coastal Plain & Foothills	
Ownership	%[b]	km^2	%[b]	km^2	%[b]	km^2	%[b]	km^2	%[b]	km^2
Federal	0	0	2	21.2	19	382.7	36	259.4	16	76.7
State	26	362.4	95	821.9	79	1,580.2	61	433.2	67	329.8
Private	70	992.4	3	22.9	2	36.6	3	19.6	11	54.1
Municipal	4	53.1	0	2.74	1	11.5	1	5.0	6	30.2
Total	11.2	1,407.9	4.4	868.7	10.5	2,011.0	4.9	717.2	2.6	490.8

[a] - Modified from Krohn *et al* (1999).

[b] - The percent was calculated by dividing the area in each ownership category in each region by the total area in conservation for that region and multiplying by 100.

The environmental variables interact with each other in complex patterns (Figure 1.2). I grouped the variables into Primary, Secondary, and Tertiary Variables according to their duration on the landscape. Primary variables (e.g. elevation and slope) are considered the physical stage for ecological events. Those intermediate in ecological causation were termed Secondary (e.g., climate, hydrology), whereas the Tertiary variables were measures of the numbers (i.e., richness) of plant and animal species.

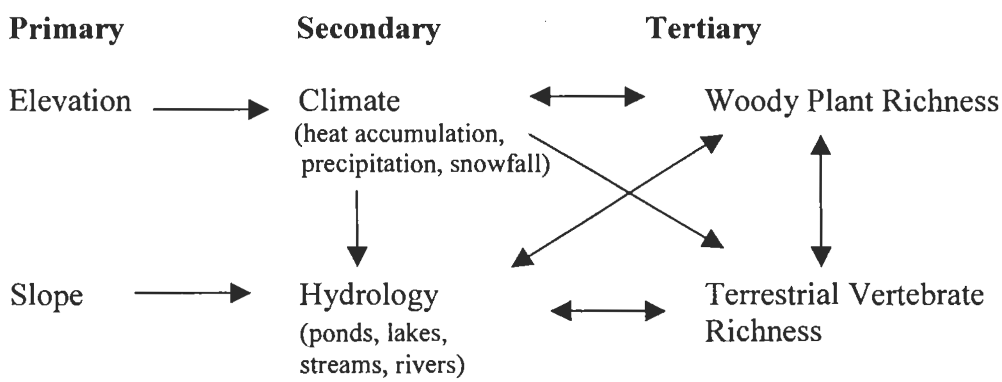


Figure 1.2. Major causal relations among environmental variables used in the statewide representational analysis of conservation lands in Maine.

Primary Variables

The occurrence of plants and animals are related to elevation and slope (Cox and Moore 1993). These relationships are due to the temperature within the troposphere which decreases at a relatively constant rate of about 7°C with each increase in altitude of 1 km (Wallace and Hobbs 1977) meaning plants and animals with different temperature thresholds will occur within temperatures they can survive. A digital elevation model (DEM), acquired from the Maine Office of GIS (MOGIS, Augusta) and developed by the U.S. Geological Survey (USGS) (Reston, VA), was assembled into a seamless model for Maine by Boone (1996) and used in this study.

Secondary Variables

Heat accumulation was designed to quantify the energy available to organisms, and represents the sum, in growing degree-days (gdd), of heat above 4.4°C (Baskerville and Emin 1969). It is related to species richness productivity and patterns (e.g., Wright 1983; Currie 1991; Boone and Krohn 2000a). Boone (1997) used the Baskerville and Emin (1969) approach to model the annual heat accumulation across Maine and explained 76% of the variation in heat accumulation across the state at the full resolution of the data (i.e., 1.86 x 1.86 km cells). Snowfall is an important factor because it can potentially limit the distribution and affect the interspecific relations of vertebrates (e.g., Krohn *et al.* 1995, Hoving 2001). Boone (1997) estimated the annual snowfall across Maine using a regression model, which included explanatory variables of latitude, elevation, and distance to coastline and explained 59% of the variation in the annual snowfall in Maine. Precipitation is also related to species distributions. Krebs (1978:185) believes "... water, alone or in conjunction with temperature, is probably the most important physical factor affecting the ecology of terrestrial organisms." Total annual precipitation was modeled for Maine using latitude, longitude, and elevation as explanatory variables, and 57% of the variation was explained (Boone 1997). All three of the climate variables are based on 30 year means, 1964 – 94.

Hydrography for the state was obtained from the MOGIS, which they modified from the USGS Digital Line Graph (DLG) maps (scale = 1:100,000). Flowing and standing water and artificial features directly related to hydrography are present in this database. Since many of the conservation area polygons in the GIS border these waterbodies and do not fully contain them, I calculated the distance to the nearest pond, lake, river or stream. I conducted this analysis in vector format due to the data being linear and detailed. I format due to the data being linear and detailed. I generated a random point sample of 100,000 for the extent of Maine and clipped Maine from that extent leaving a 53,440 random point sample. I clipped out the random points from conservation (n = 2,947) and non-conservation lands (n = 50,493) and calculated the distance from each random point to the nearest water body and graphed the distances of conservation versus non-conservation lands. I grouped the distances into 1 – 500, 500 – 1000, 1001 – 1500, > 1500 m.

To distinguish between lakes and ponds in its classification, I created a frequency distribution graph based on the area of the waterbodies in Maine (Figure 1.3). Inspecting the graph, I decided to use 20 ha as the threshold. With this threshold, there are 4,769 ponds and 1,349 lakes in the database. To distinguish between rivers and streams, MOGIS modified the DLG layer by classifying double line stream features as rivers and single line stream features as streams (MOGIS 1997).

Tertiary Variables

Vegetation patterns on a landscape influence both abiotic and biotic processes (e.g., Turner 1990, Chokkalingam 1998). In Big Reed Forest Reserve, the largest old growth forest in New England, distribution of vegetation was strongly associated with environmental parameters such as soil type, slope, aspect, and elevation (Chokkalingam 1998). Boone and Krohn (2000b) developed woody plant ranges, by creating Arc/Info grids based upon dot maps published in McMahon (1990). The species range maps were generalized into a 1.86 x 1.86 km cell size grid and the number of species predicted to use each cell was tallied to create a richness grid.

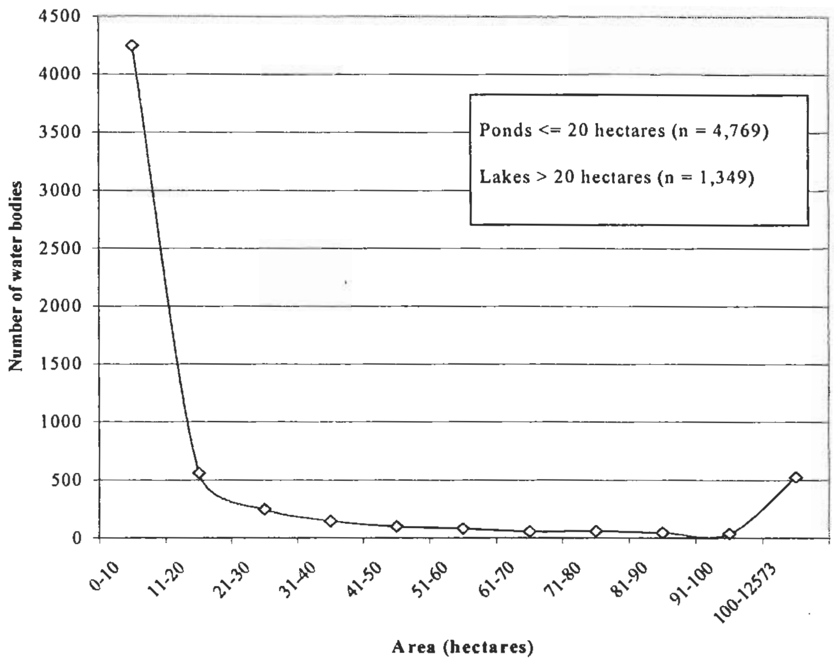


Figure 1.3. Frequency distribution of water bodies (n = 6,118) used to define lakes versus ponds.

Terrestrial vertebrate richness is a measure of non-fish, non-marine vertebrates that regularly breed in Maine as listed by Boone and Krohn (1998a,b). Terrestrial vertebrate species ranges were modeled and mapped by 324 km^2 (1.86 x 1.86) blocks overlapped by at least 50% and were published in Boone and Krohn (2000a). Richness totals were created from the species models by tallying the number of species predicted to use each cell. In Maine, there were 275 terrestrial vertebrates mapped, based upon a grid (cell size = 1.86 x 1.86 km), with 119 having range limits in the state (Boone and Krohn 2000a).

Aggregated Variable Analysis

To identify the areas overlapping with highly under-represented variables, I aggregated the highly under-represented cells from the Primary and Secondary variables. Because the Tertiary variables are directly related to the Primary and Secondary variables (Boone and Krohn 2000a,b), they are displayed and not used in the aggregated analysis. The cells in the non-conservation lands grid for the Primary and Secondary variables were assigned a value, or "score", of '1' if it was highly under-represented and a score of '0' if it was well- or over-represented. The non-conservation land grids for the variables were then aggregated into one grid with all the scores added together and mapped. The map is similar to a richness map with a legend that illustrates how many highly under-represented environmental variables are present for each cell not in conservation. The aggregated scores for each biophysical region were added together and divided by the number of cells to obtain an average.

Representational Types

When comparing the percent values in conservation to the percent values in non-conservation, it is critical to define which variable classes are under-represented and which are not. This definition depends on two parameters: (1) the difference between the percent values (i.e., representation differences); and (2) the amount of the differences. I calculated a relative difference (i.e., dividing the percent in conservation by the percent in non-conservation) between the two percent values in order to determine what variable classes were under-represented. To understand the effect that the relative difference had on the results, I calculated the absolute difference by subtracting the percent in conservation by the percent in non-conservation.

Threshold Level Analyses

To compare the results using relative and absolute differences, I needed a cutoff value for the absolute difference to determine if a variable class was under-represented. Because the absolute difference between conservation and non-conservation lands is a straight subtraction, it does not take into account the size of the area in each variable class. For example, one variable class may have 2% in conservation and 4% in non-conservation, meaning there is half of that variable class in conservation compared to what is in non-conservation. In that case we would want our threshold level to be a 2% difference between conservation and non-conservation lands to ensure detection of the under-representation of this variable class. Unfortunately, this threshold level would result in a variable class with 34% in conservation and 36% in non-conservation also being labeled under-represented, though the difference is very slight. In order to address this issue, I looked at threshold levels of 2%, 4%, and 6%, in order to see what variable classes were under-represented by more than 4% and 6%, realizing that this may have dropped out variable classes with a small area that were under-represented. A comparison could then be made to 2%, 4%, and 6% absolute threshold levels and a relative threshold level of 0.5 or less.

RESULTS

Primary Variables

Elevation in Maine ranges from 0 to 1359 m above mean sea level (msl) (Figure 1.4A). Approximately 76% of the state lies between 0 and 200 m and approximately 0.1% of the state lies above 1000 m. Between 0 and 200 m, there is 54% of the cells on non-conservation lands versus 23% of the cells on conservation and a relative difference of 0.4 meaning highly-under-represented (Figure 1.4A). In elevations between 201 and 300 m, the percent of cells in conservation lands is 14.7% compared to 15.5% in non-conservation lands, resulting in a relative difference of about 1.0 (i.e., well-represented). The elevations greater than 300 m all have a relative difference greater than 1.0. Areas in southern and eastern Maine were the most under-represented in terms of elevation (Figure 1.4B).

The degree of slope in Maine ranges from 0 to 42. Approximately 40% of the state has a slope of zero degrees and 76% has a slope less than 5 degrees. Degrees of slope between 0 and 4 are under-represented by conservation lands with a relative difference of 0.8 (1 and 2 degrees) and 0.9 (0, 3, and 4 degrees). Degrees of slope greater than 5 have a relative difference greater than 1.0 and are considered well-represented (Figure 1.5A). The under-represented areas (degree of slope between 0 and 4) are located across the state. The well-represented areas are dominant in western and northcentral Maine and coincide with the interior and western mountains (highly sloped areas) (Figure 1.5B).

Secondary Variables

Heat accumulation values range between 956 and 3,375 ^{o}C days/year with most of the state (~ 78%) between 2,000 and 3,000 ^{o}C days/year and less than 1% between 1,000 and 1,500 ^{o}C days/year (Figure 1.6A). The range of 1,000 to 2,500 ^{o}C days/year are

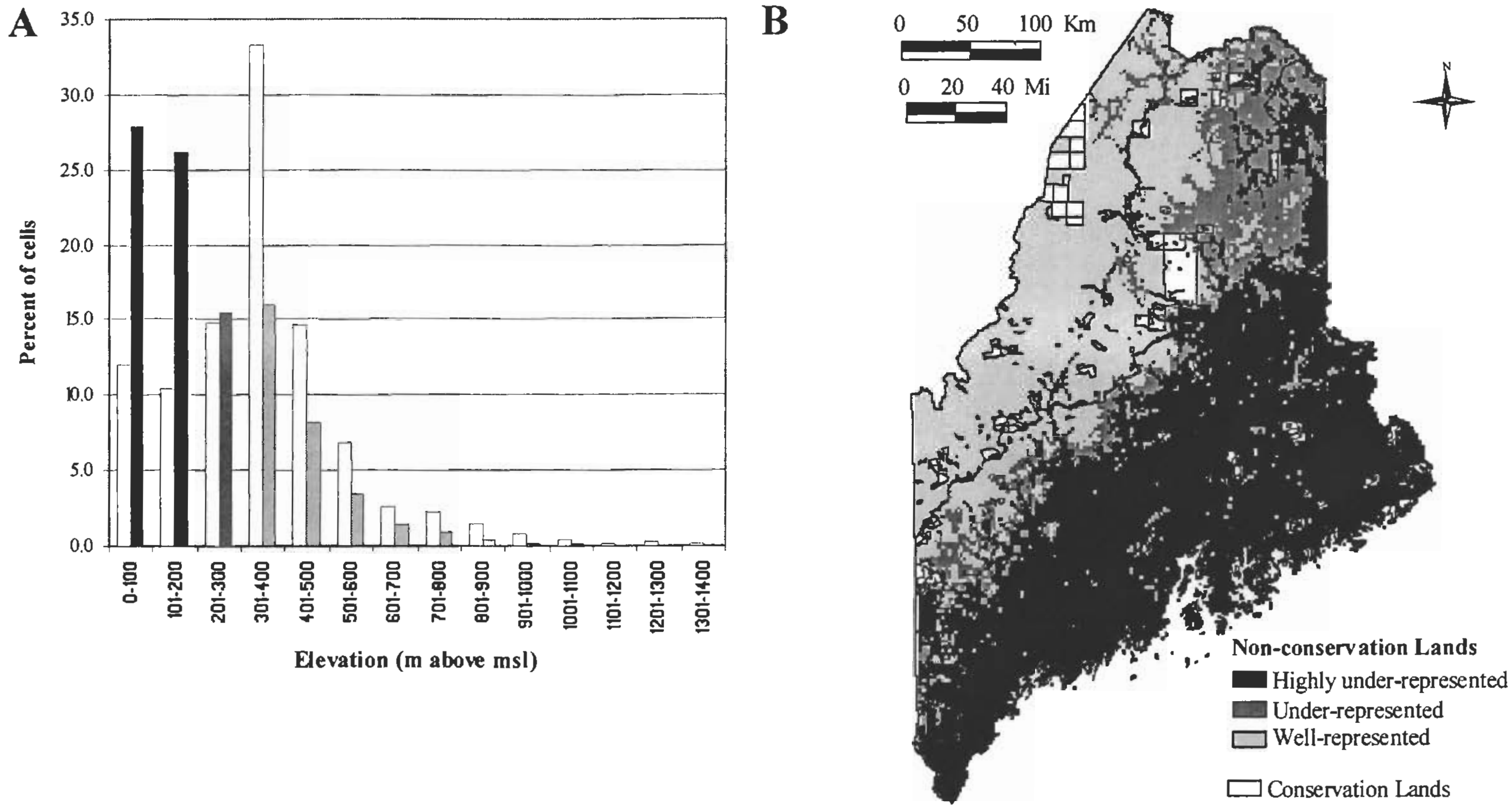


Figure 1.4. Distribution of elevations (m above msl) across Maine by conservation (left bar) and non-conservation areas (right bar) (A), and the representation of elevations on non-conservation areas in Maine (B). Under-representation is defined as a relative difference of 0.5 or less between conservation and non-conservation land percents.

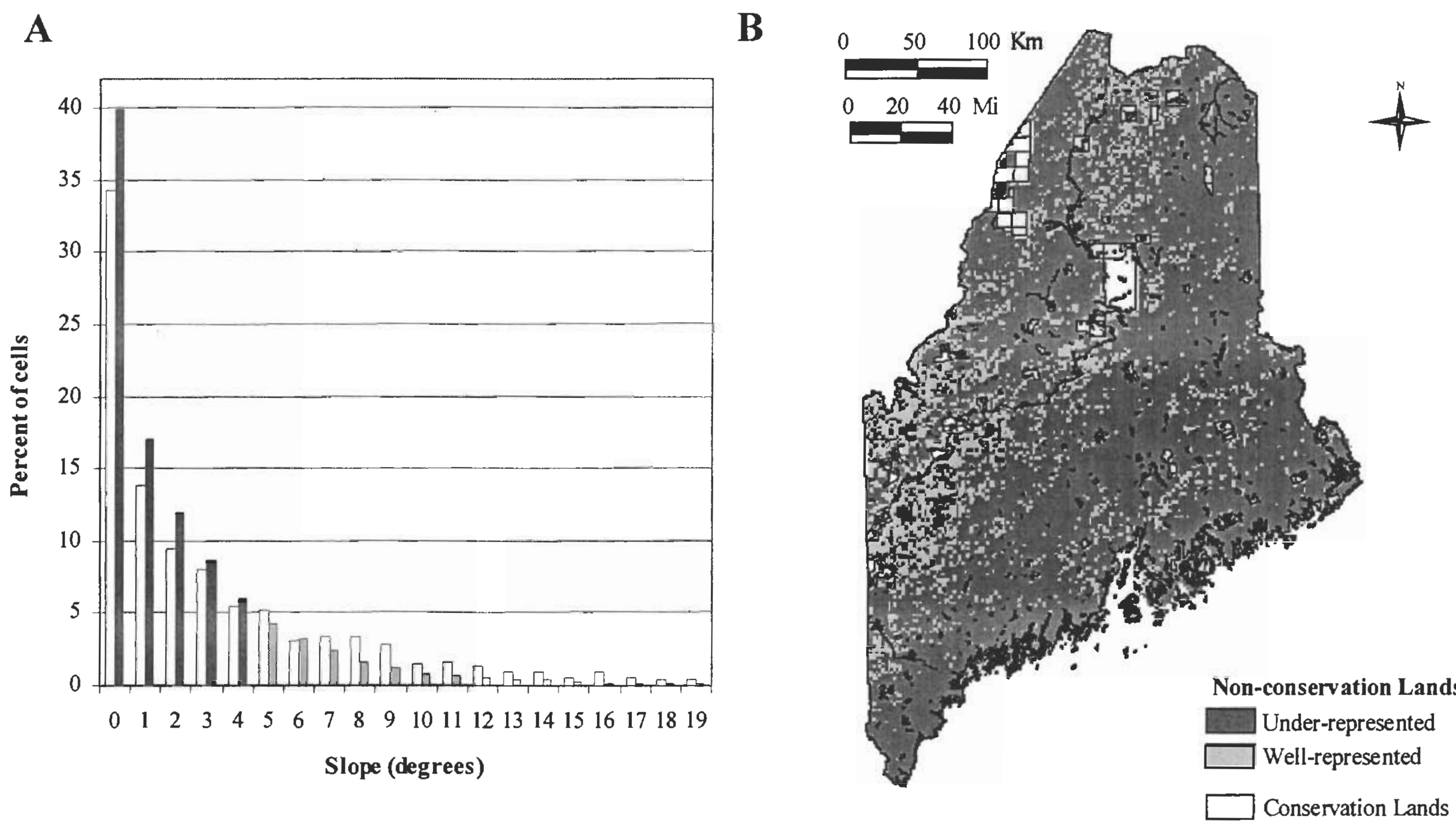


Figure 1.5. Distribution of slope (in degrees) across Maine by conservation (left bar) and non-conservation areas (right bar) (A), and the representation of slope on non-conservation areas in Maine (**B**). Under-representation was defined as a relative difference of 0.5 or less between conservation and non-conservation land percents.

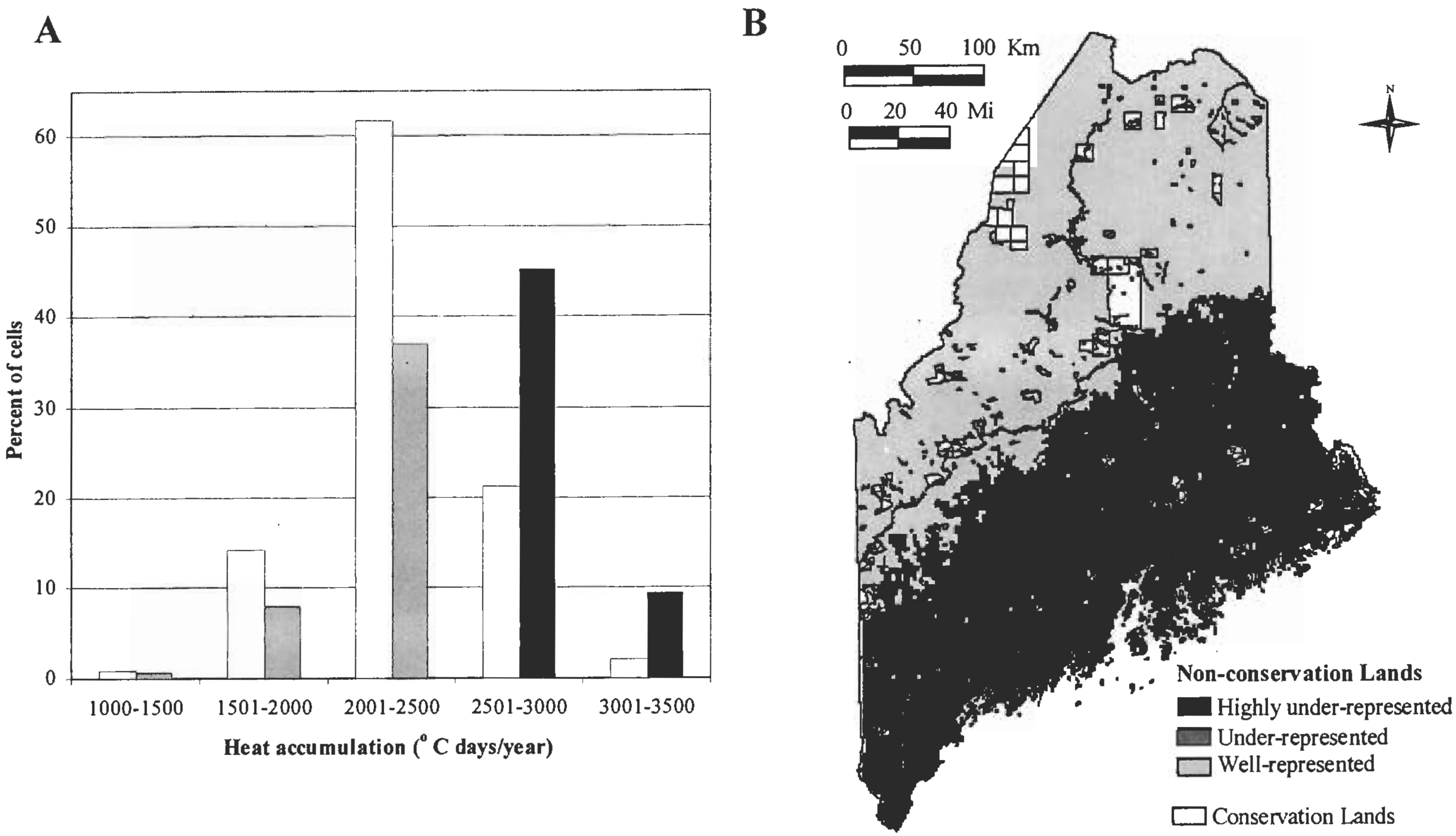


Figure 1.6. Distribution of heat accumulation (° C days/year) across Maine by conservation (left bar) and non-conservation (right bar) areas (**A**), and the representation of heat accumulation on non-conservation areas in Maine (**B**). Under-representation defined as a relative difference of 0.5 or less between conservation and non-conservation land percents.

well-represented by conservation lands (Figure 1.6A). The range of 2,500 to 3,500 ° C days/year are highly under- represented by conservation lands with ~23% in conservation lands and 54% in non-conservation lands with a 2%, 4%, and 6% threshold levels (Figure 1.6A). The under-represented areas are along the south and central portions of the state (Figure 1.6B).

Approximately 92% of Maine experience a total annual snowfall of between 161 – 320 cm. The areas with the least snowfall (101 – 160 cm) are under-represented by conservation lands with a relative difference of 0.6 (Figure 1.7A). Cells with snowfall between 161 and 240 have 19% in conservation and 49% in non-conservation, leaving conservation lands highly under-represented. The 241 – 320 cm and 321 - 480 cm ranges of snowfall are well-represented with a relative difference of 1.6 and 2.8, respectively. The highly under-represented areas are in the south, central, and eastern portions of the state, except for the areas right along the coast, which are well–represented (Figure 1.7B).

Ninety percent of the state has a total annual precipitation between 91 and 120 cm. The values 71 to 80 cm are highly under-represented with a relative difference of 0.3 and 0.1% in conservation and 0.2% in non-conservation (Figure 1.8A). Precipitation values ranging from 81 to 100 and 121 to 180 cm are well-represented and 101 to 120 cm are under-represented. The highly under-represented areas, ranging between 71 and 80 cm, are located in a few areas in the northwest tip of the state (Figure 1.8B).

The distance ranges of 1 to 500 m and 1,001 to 1,500 from the points to the nearest pond were well-represented by conservation lands with a relative difference of 1.3 (Figure 1.9A). Distances between 500 and 1,000 m and greater than 1,500 m are slightly under-represented with relative differences of 0.98 and 0.89, respectively. The areas

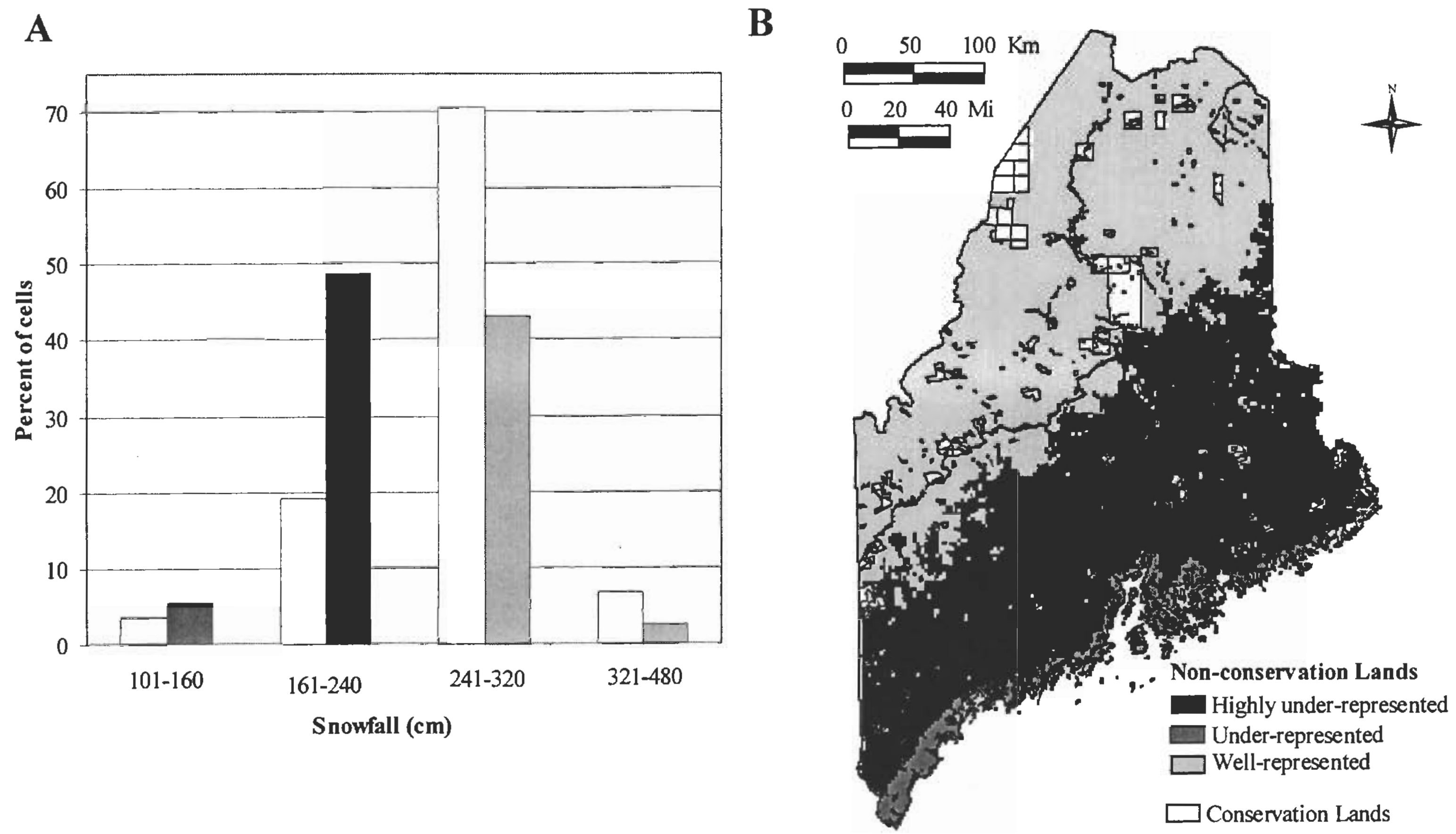


Figure 1.7. Distribution of total snowfall (cm/yr) across Maine by conservation (left bar) and non-conservation (right bar) areas (**A**), and the representativeness of non-conservation areas in Maine (**B**). Under-representation is defined as a relative difference of 0.5 or less between conservation and non-conservation land percents.

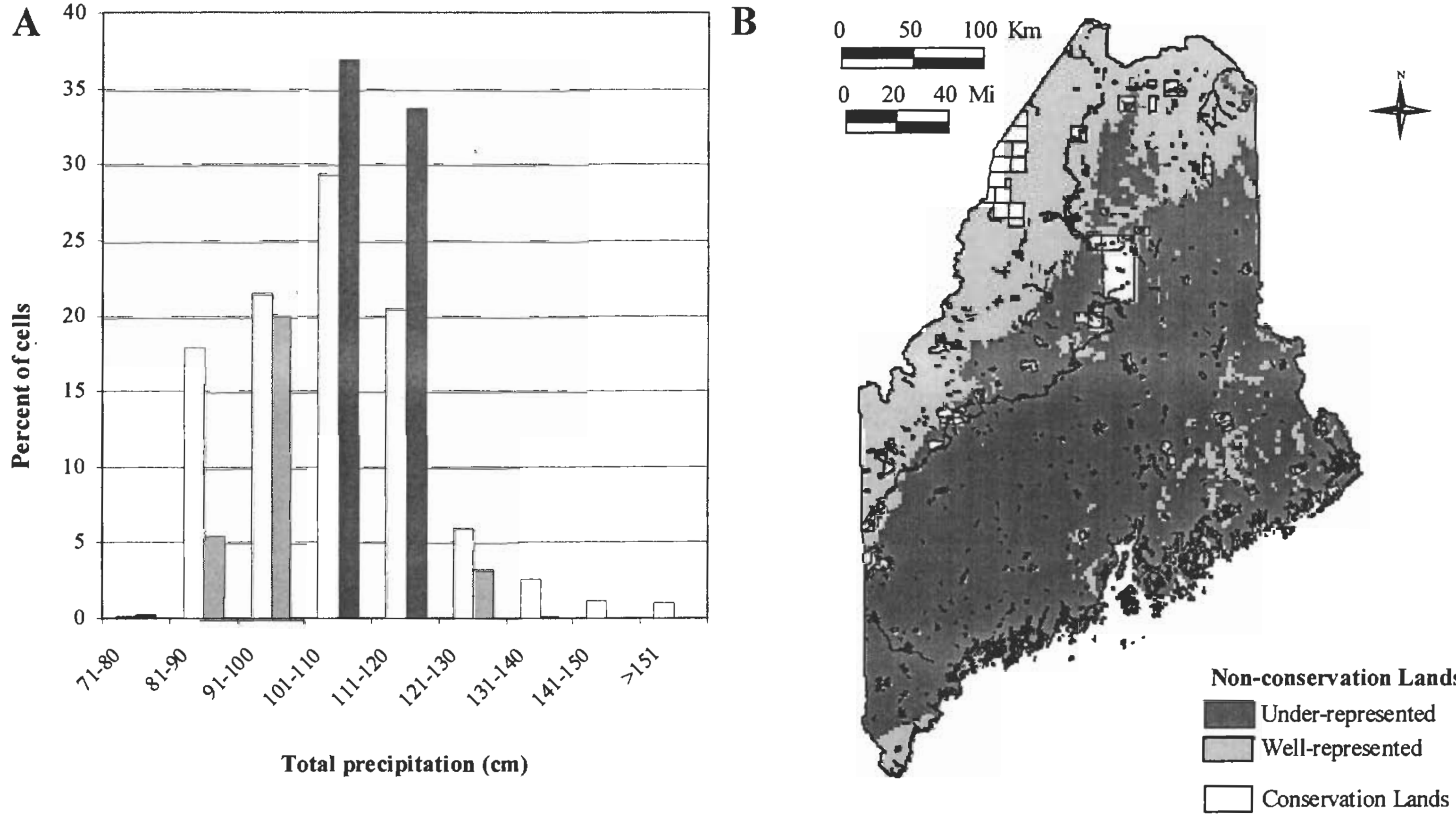


Figure 1.8. Distribution of total precipitation (cm/yr) across Maine by conservation (left bar) and non-conservation areas (right bar) (**A**), and the representation of precipitation on non-conservation areas in Maine (**B**). Under-representation is defined as a relative difference of 0.5 or less between conservation and non-conservation land percents.

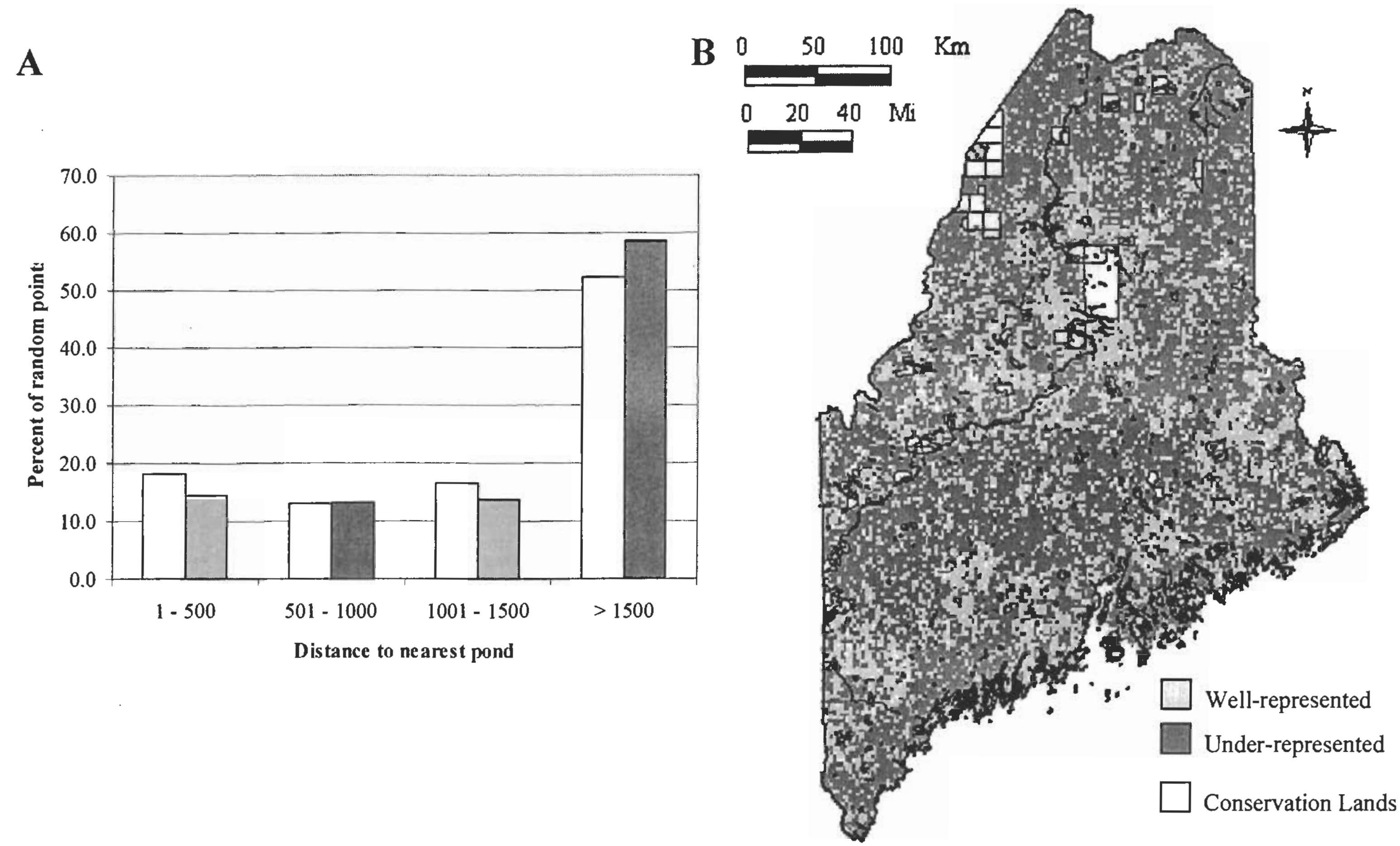


Figure 1.9. Distance to the nearest pond (m) across Maine by conservation (left bar) and non-conservation (right bar) areas (**A**), and the representation of ponds on non- conservation areas in Maine (**B**). Highly under-represented is defined as a relative difference of 0.5 or less between conservation and non-conservation land percents.

under-represented by conservation lands are scattered throughout the state (Figure 1.9B).

Fifty-nine percent of the random points (31,715 out of 53,686) were at distances between 1 and 4,000 m to the nearest lake. Conservation lands well-represent the distances to the nearest lake from 1 to 1,000 m. (Figure 1.10A). Distances greater than 1,500 m to the nearest lake were under-represented with a relative difference of 0.9 (Figure 1.10A). The areas under-represented by conservation lands are scattered throughout the state (Figure 1.10B).

Streams occurred throughout the state and were equally represented on conservation and non-conservation lands. Therefore, the streams were omitted from further analysis. In terms of rivers, about half of the random points were within 8,000 m to the nearest river. The distances between 1 and 500 m to the nearest river were well-represented by conservation lands with a relative difference of 1.3 (Figure 1.11A). The distances greater than 500 m are slightly under-represented by conservation lands (Figure 1.11A). The under- and well-represented areas occur throughout the state, with the well-represented areas following close to the rivers (Figure 1.11B).

Tertiary Variables

Statewide woody plant richness ranges from 100 in the north to 200 in southern Maine. The distribution is fairly even for each range of richness values (between 5 and 13%), except 100 to 110 which occupies 23% of the state (Figure 1.12A). The ranges between 141 to 150 and 171 to 200 were highly under-represented on conservation lands (Figure 1.12A). The range between 100 and 130 were well-represented, and the 131 – 140 and 151 – 170 ranges were under-represented. The highly under-represented areas are dominant in the Coastal Plain and Foothills region and in the southeast part of the state (Figure 1.12B).

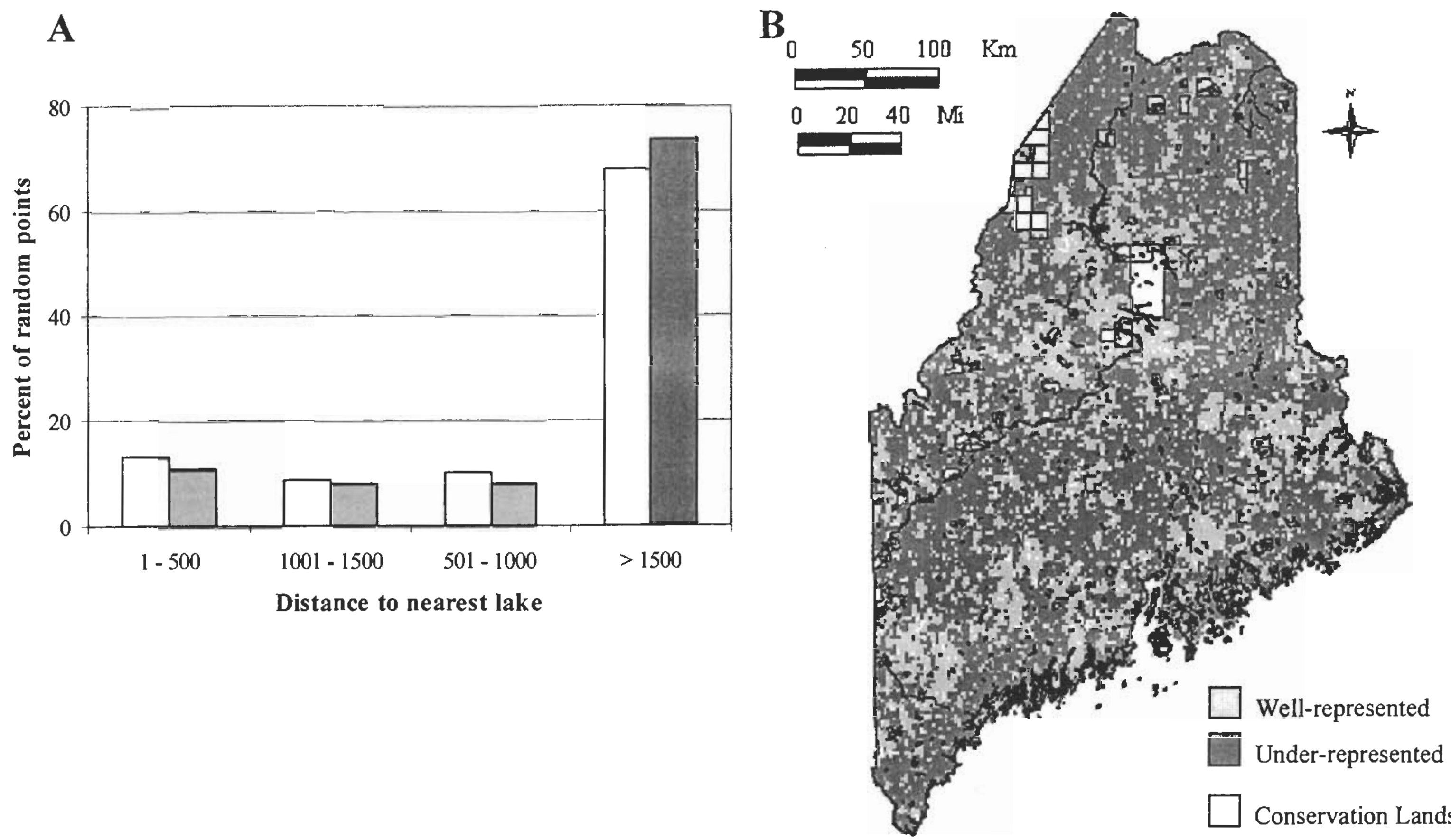


Figure 1.10. Distance to the nearest lake (m) across Maine by conservation (left bar) and non-conservation (right bar) areas (**A**), and the representation of lakes on non-conservation areas in Maine (**B**). Highly under-represented is defined as a relative difference of 0.5 or less between conservation and non-conservation land percents.

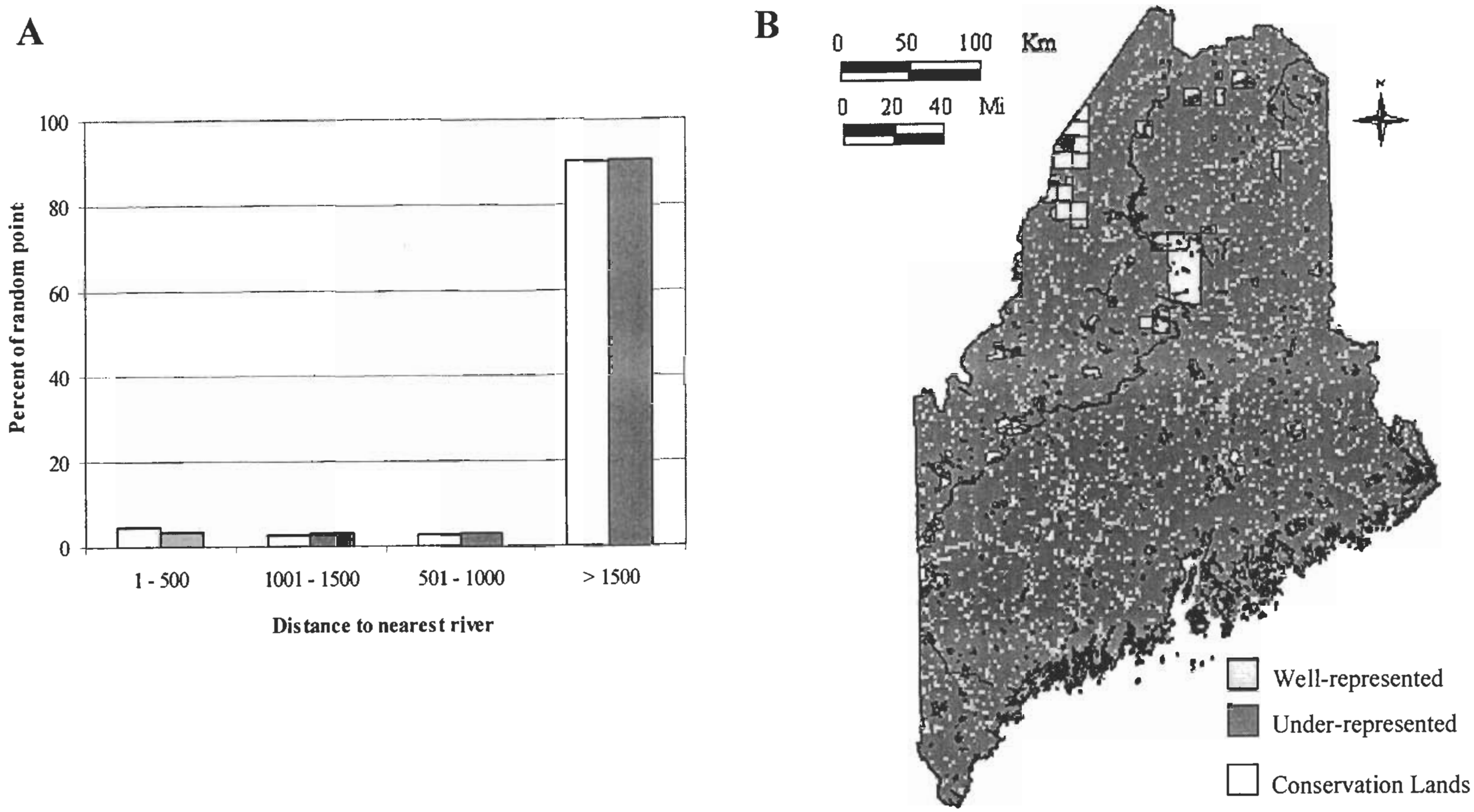


Figure 1.11. Distance to the nearest river (m) across Maine by conservation (left bar) and non- conservation (right bar) areas (**A**), and the representation of rivers on non-conservation areas in Maine (**B**). Highly under-represented is defined as a relative difference of 0.5 or less between conservation and non-conservation land percents.

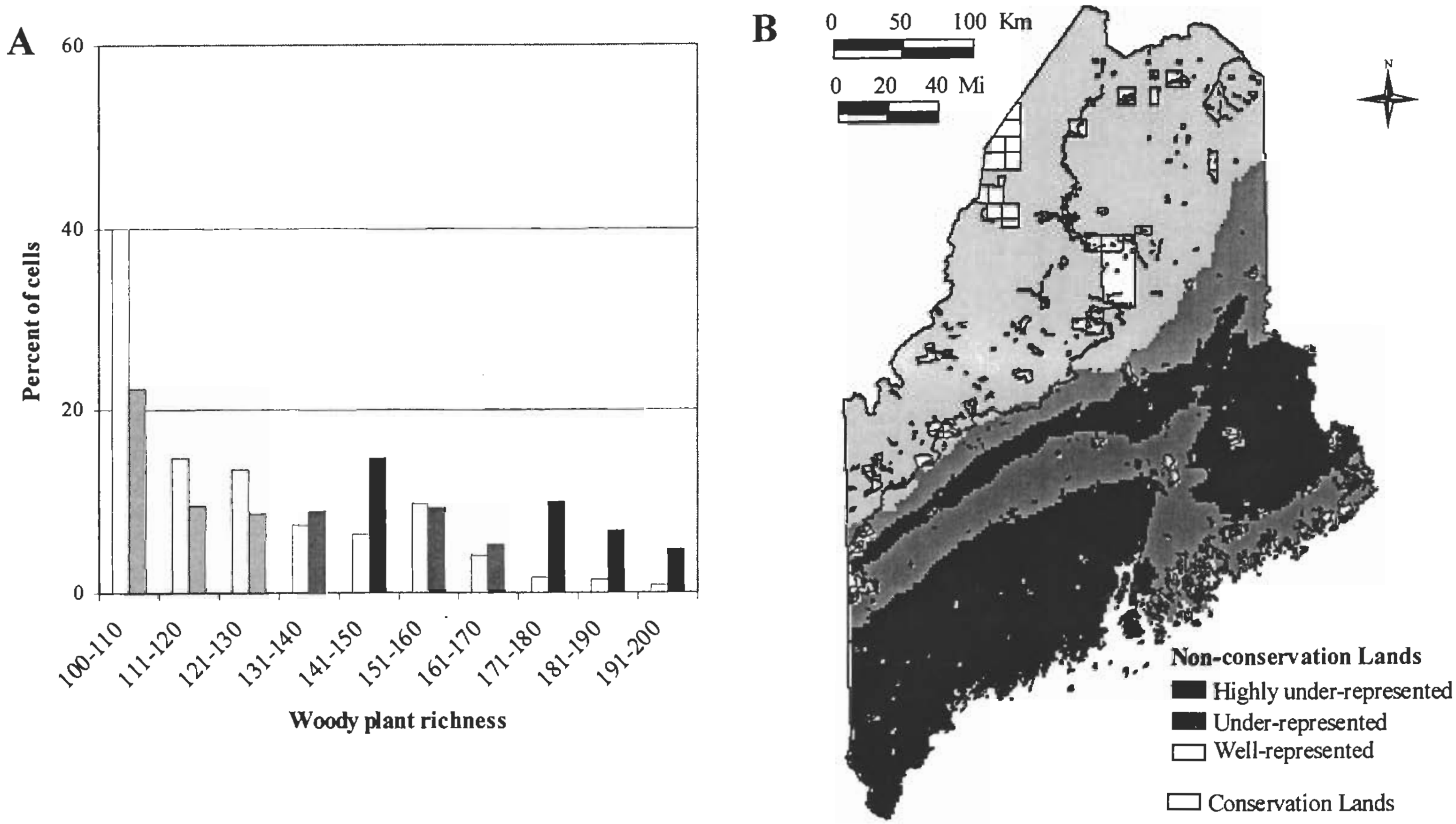


Figure 1.12. Distribution of woody plant richness across Maine by conservation (left bar) and non-conservation (right bar) areas (**A**), and the representation of woody plant richness on non-conservation areas in Maine (**B**). Under-representation is defined as a relative difference of 0.5 or less between conservation and non-conservation land percents.

Statewide, vertebrate richness ranges from 193 to 233 species with approximately 46% of the state in the 210 to 221 range (Figure 1.13A). Terrestrial vertebrate richness values between 193 and 215 were well-represented (Figure 1.13A). Richness values between 216 and 221 were highly under-represented by conservation lands and richness values between 222 and 233 were under-represented (Figure 1.13A). The highly under-represented areas run along central-southern Maine in an east to west band (Figure 1.13B).

Aggregated Variables

The highly under-represented cells of the Primary Variables (e.g., elevation and slope) were aggregated into one layer and mapped (Figure 1.14A). The highly under-represented areas cover most of the following regions: St. John Valley, Eastern Foothills and Lowlands, and the Coastal Plain and Foothills (Table 1.3). The Coastal Plain and Foothills and the Eastern Foothill and Lowland regions have approximately 100% of elevation values highly under-represented by conservation lands.

When the secondary variables (e.g., three climate and three hydrographic) were aggregated and mapped, the most highly under-represented values were in the Coastal Plain and Foothills Region, although there is considerable variation across Maine (Figure 1.14B). The climate variables are highly under-represented in the Eastern Foothills and Lowlands Region and the Coastal Plain and Foothills Regions (Table 1.3).

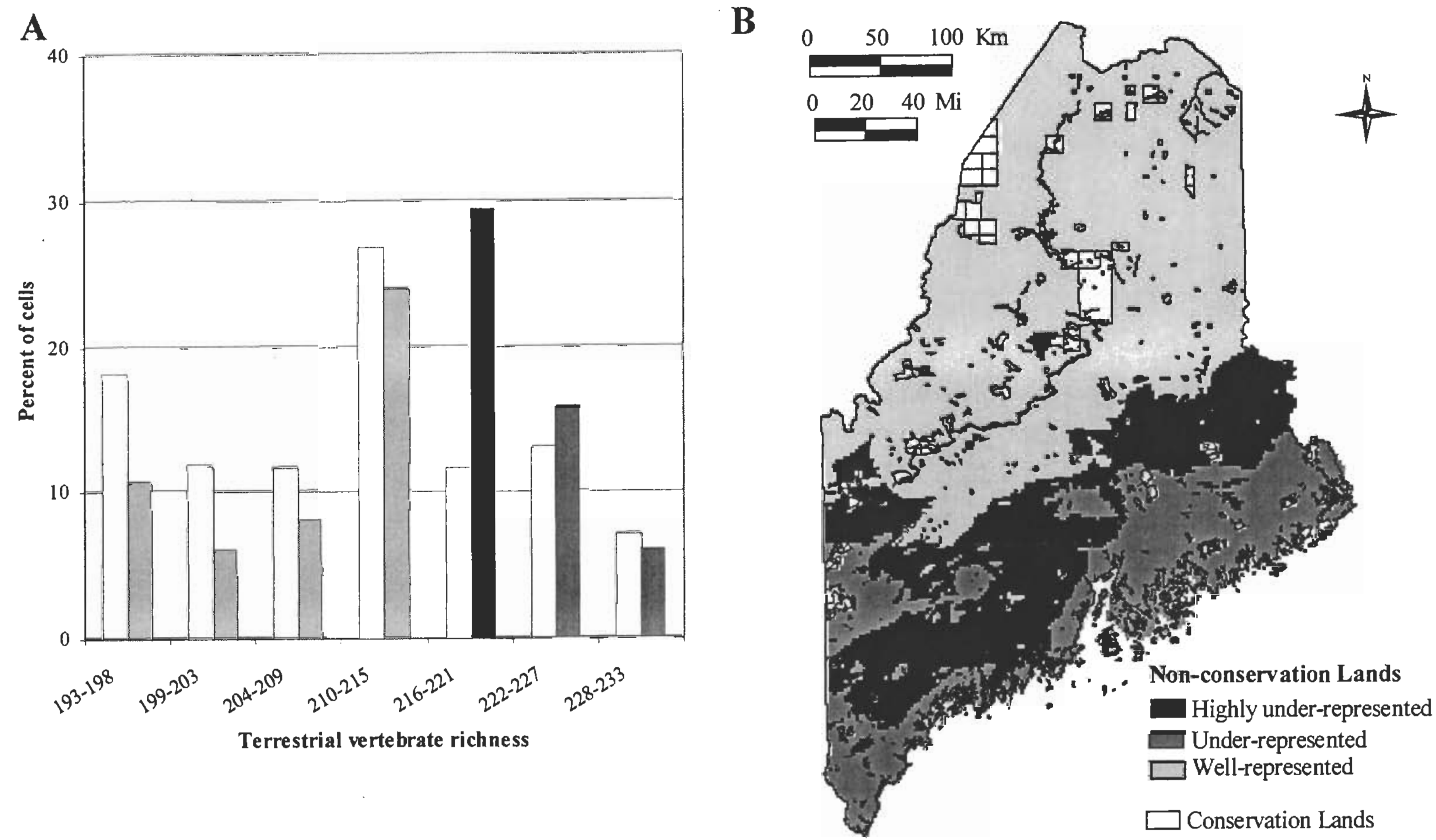


Figure 1.13. Distribution of terrestrial vertebrate richness across Maine by conservation (left bar) and non-conservation (right bar) areas (**A**), and the representation of vertebrate richness on non-conservation areas in Maine (**B**). Highly under-represented is defined as a relative difference of 0.5 or less between conservation and non-conservation land percents.

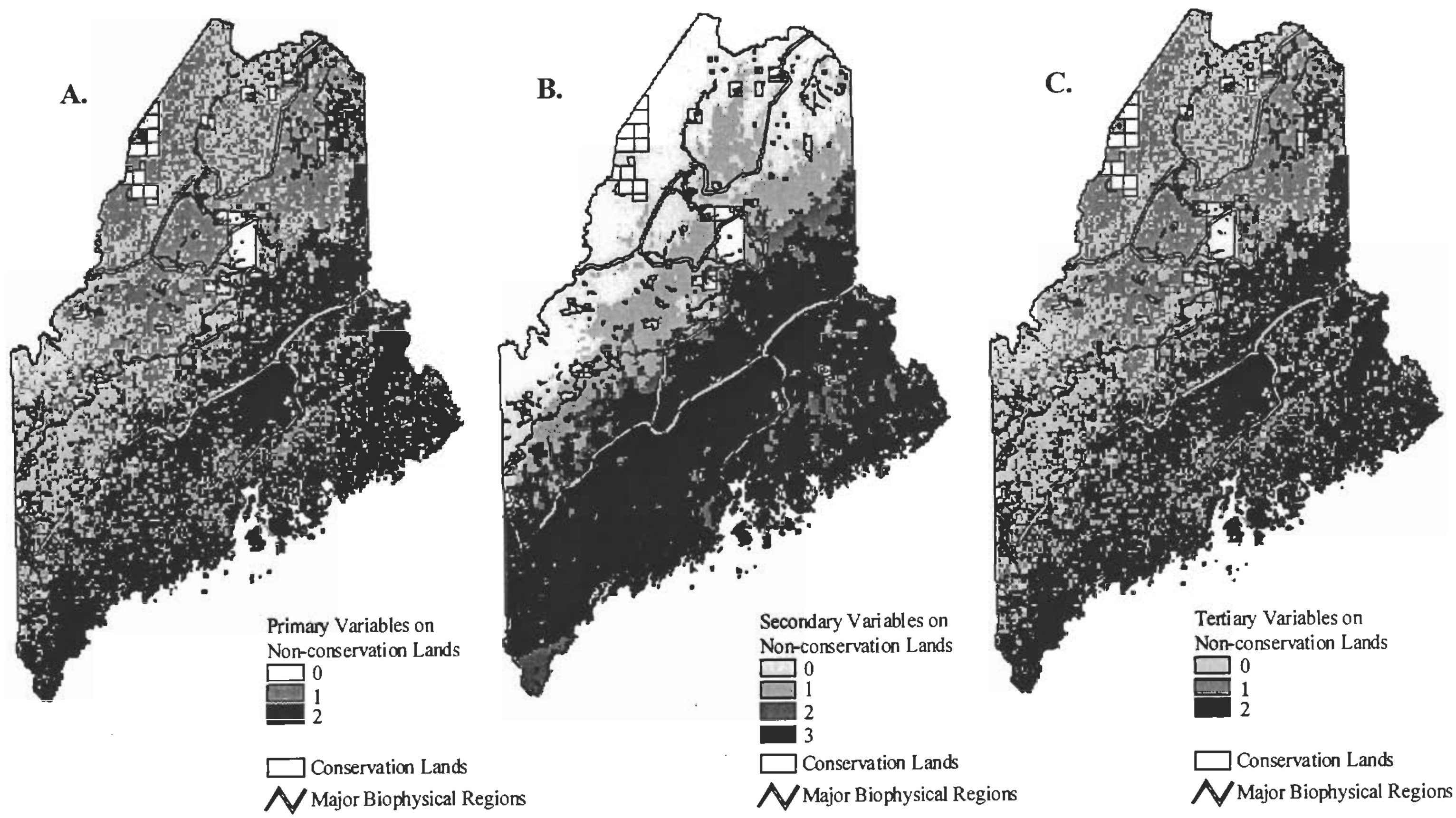


Figure 1.14. Highly under-represented cells aggregated for Primary (A), Secondary (B), and Tertiary (C) variables shown on non-conservation lands in Maine.

Table 1.3. The percent of each major biophysical region in highly under-represented variable classes on non-conservation lands.

Variables (classes highly under-represented[b])	**Major Biophysical Regions[a]**				
	St. John Upland	**St. John Valley**	**Western & Interior Mountains**	**Eastern Foothills & Lowlands**	**Coastal Plain & Foothills**
Primary					
Elevation (0 - 200 m)	18.9	86.4	25.2	99.9	99.5
Slope	0	0	0	0	0
Secondary					
Heat accumulation (2501-3500 °C days)	28.4	38.7	42.3	99	100
Total snowfall (161 - 240 cm)	0	40.2	18	85.6	86.9
Total precipitation (71 - 80 cm)	2.2	0	0	0	0
Lakes	0	0	0	0	0
Ponds	0	0	0	0	0
Rivers	0	0	0	0	0
Tertiary					
Woody plant richness (141 - 150, 171 - 200)	78.4	39.1	44.2	76.2	91.6
Terrestrial vertebrate richness (216 - 221)	0	10.7	26.9	36.1	62.3

[a] - Modified from Krohn *et al.* (1999)

[b] - Highly under-represented variable classes were defined as those with a relative difference of ≤ 0.5 between conservation and non-conservation land percents.

The highly under-represented cells for the Tertiary Variables (e.g., woody plants and terrestrial vertebrate richness) were aggregated and mapped, showing that southern Maine, and an east–west band across central Maine, to be the most under-represented (Figure 1.14C). The Coastal Plains and Foothills Region have 91.6% of woody plant richness values and 62.3% of terrestrial vertebrate richness values highly under-represented by conservation lands (Table 1.3).

The highly under-represented cells were aggregated for the Primary and Secondary Variables and mapped with values ranging from 0 to 4 out of a total of 8 variables (Figure 1.15). The mean, median, and range of under-represented variables were calculated for the Primary and Secondary variables (Table 1.4). The Coastal Plains and Foothills region and the Eastern Lowlands and Foothills region showed the highest mean numbers of under-represented variables, with 2.8 and 2.9 respectively, followed in order by the St. John Valley Interior Foothills (1.4), the Western and Interior Mountains (0.6), and the St. John Uplands Region (0) (Table 1.4).

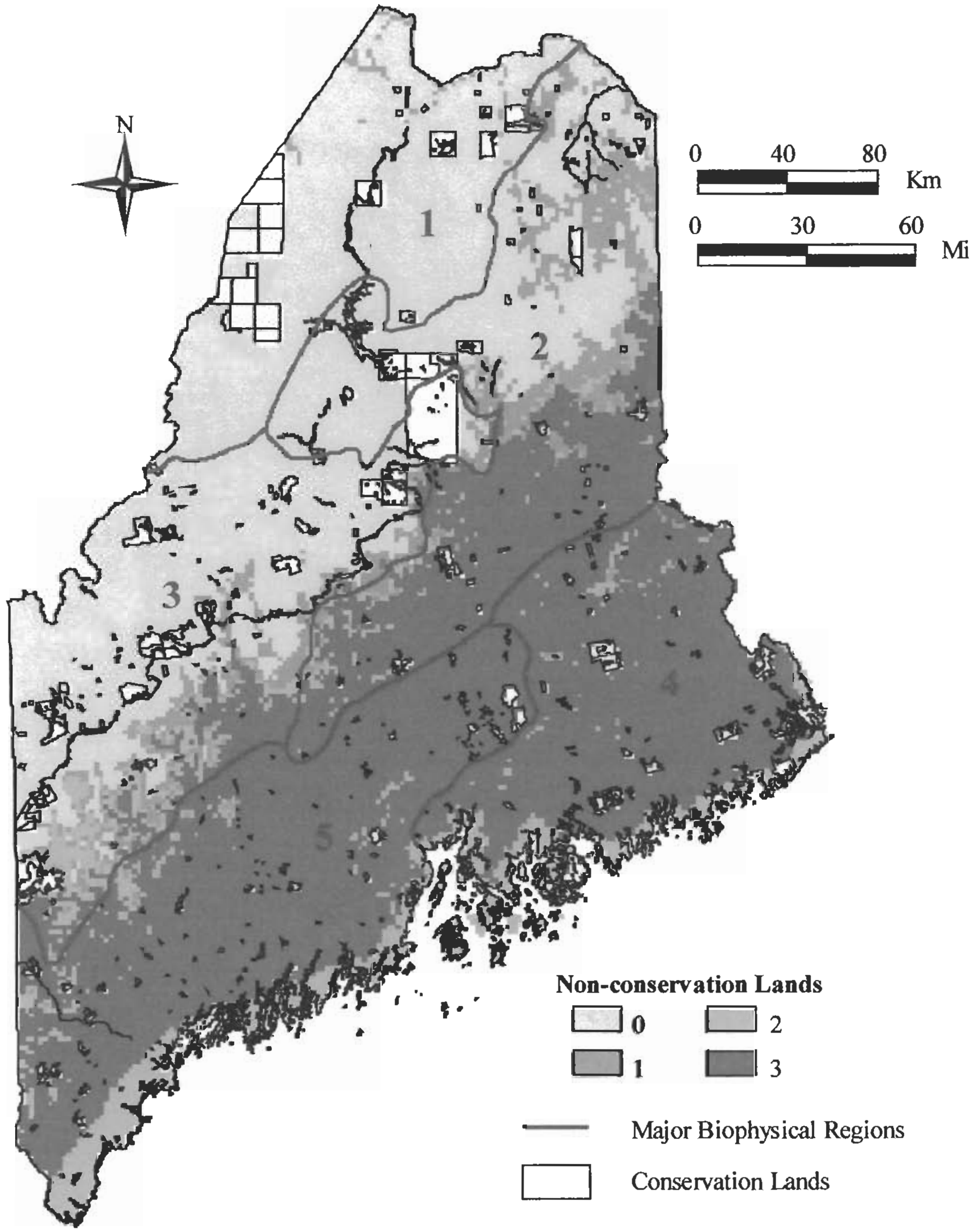


Figure 1.15. Aggregated values of highly under-represented variables by 1.86 x 1.86 km cells on non-conservation lands in Maine (based on relative differences; see text). Major biophysical regions modified from Krohn *et al.* (1999).

Table 1.4. Statistics and conservation priorities of regions, based on aggregated values of highly under-represented variables in each major biophysical region of Maine.

Major biophysical regions[a]	Aggregated Values per Region [b]			Overall Priority
	mean	median	range	
St. John Uplands	0	1	0 - 2	5
St. John Valley Interior Foothills	1.4	2	0 - 3	3
Western and Interior Mountains	0.6	2	0 - 3	4
Eastern Lowlands and Foothills	2.9	2	1 - 3	1
Coastal Plains and Foothills	2.8	2	1 - 3	2

[a] - Modified from Krohn *et al.* (1999).

[b] - Regional means calculated by adding the aggregated scores per cell and dividing by the total number of cells in the region.

Threshold Analyses

The effects of using a relative difference with a threshold level of 0.5 to define the representation of the variable classes was assessed by comparing the absolute difference with three threshold levels (i.e., 2, 4, and 6 %). The Coastal Plains and Foothills Region was the most under-represented with 2, 4, and 6% absolute threshold levels, with the Eastern Lowlands and Foothills Region a close second. The under-represented variable classes did not change significantly using an absolute difference, with the exception of the hydrography variables (Table 1.5). The hydrography variables were not under-represented according to the threshold level of ≤ 0.5 because they were under-represented by only a small degree, as shown in the absolute threshold level of 4% and 6% (Table 1.5).

DISCUSSION

Maine Gap Analysis (ME-GAP), the only other analysis of elements of Maine's biodiversity done statewide, also concluded that southern Maine was most in need of additional conservation lands (Krohn *et al.* 1998). ME-GAP found, based on both the locations of endangered inland vertebrates and the greatest number of species regularly breeding in Maine, along with the densest human population areas and the least density of conservation lands, that southern Maine was in the greatest need of additional conservation lands. This analysis, based on an entirely different method (hotspots vs. representation), came to similar conclusions, suggesting that southern and eastern Maine are in need of more conservation lands. This conclusion is opposite the thinking of many preservationists, who argue for the protection of some of the remaining large continuous

Table 1.5. The variable classes highly under-represented on conservation lands using a relative difference versus an absolute difference between the percent in conservation versus non-conservation lands.

Variable Type	Absolute Threshold Levels [a]			Relative Threshold Levels [b]		
	2%	4%	6%	0.3	0.5	0.8
Primary						
Elevation (m above msl)	0 - 200	0 - 200	0 - 200	0 - 200	0 - 200	none
Slope (degrees)	0 - 2	0	none	none	none	2
Secondary						
Heat accumulation (°C days)	2,501 - 3,500	2,501 - 3,500	2,501 - 3,500	3,001-3,500	2,501 - 3,500	2,501 - 3,500
Total snowfall (cm)	101 - 240	161-240	161 - 240	161-240	161-240	161-240
Total precipitation (cm)	101 - 120	101 - 120	101 - 120	none	71 - 80	71 - 80, 101 - 120
Ponds (m)	2,001 - 6,000	4001 - 6000	none	none	none	none
Lakes (m)	2,001 - 6,000	none	none	none	none	4,001 - 6,000
Rivers (m)	2,001 - 6,000	none	none	none	none	2,001 - 6,000, > 20,000
Tertiary						
Woody plant richness	141-150, 171-200	141-150, 171-190	141-150, 171-180	171-200	141-150, 171-200	141-150, 161-200
Terrestrial vertebrate richness	216-227	216-221	216-221	none	216 - 221	216 - 221

[a] - Absolute threshold levels defined as the percent on conservation lands minus the percent on non-conservation lands.

b - Relative threshold levels defined as the percent on conservation lands divided by the percent on non-conservation lands.

tracts of wildlands and natural areas in the northeast by acquiring more public lands in northern Maine (e.g., Irland 1996, Kellett 1989).

The assessment of an area for conservation lands, whether for a state, country, or ecoregion, should answer the following three fundamental questions: (1) What landscapes should be conserved?, (2) Where should they be located?, and (3) How much land should be conserved? Conservation lands must be considered as units to fulfill their functional role as part of a landscape mosaic (Noss 1987). To determine what landscapes should be put into conservation, consideration is usually given to what rare and endangered species, exemplary communities, or unusual geological features the areas contain (Noss 1987). Realistically, the selection of conservation lands is generally based on a wider range of criteria including politics, aesthetics, recreational opportunities, availability, willing land owners to sell, and land prices.

Representational analyses of conservation lands address two of the three fundamental questions stated above (i.e., what and where). By determining what landscapes are under-represented in existing conservation lands, the question of where new conservation lands should be located is answered. In this study of Maine, the 8 abiotic variables compared on and off conservation lands showed the areas with low elevation, high growing degree days, and low to medium amounts of snowfall are the most under-represented in the state. In addition, the biotic variables analyzed show the areas with high woody plant and terrestrial vertebrate richness numbers were the most under-represented. The analysis also showed these areas with the most under-represented variables were concentrated in the Coastal Plain and Foothills Region (i.e., southern Maine) and the Eastern Lowland and Foothills Region (i.e., southeastern Maine).

As for how much land should be put into conservation, representational analyses allow one to calculate the area of under-represented landscapes needed to obtain a conservation goal. For example, Maine's goal is to double the amount of public and private conservation lands to 3,971 km^2 by the year 2020 (Maine State Planning Office 1997). Areas with 3 out of 4 under-represented variables across the state comprise 36,091 km^2, or 43% of the state, thus leaving consider flexibility as to where to locate these areas for Maine's land conservation goal. Just within the Coastal Plains and Foothills Region (i.e., southern Maine), there is 15,471 km^2 with 3 out of 4 under-represented variables and in the Eastern Lowlands and Foothills Region there is 10,991 km^2.

Representational analyses identify the range of natural variation defined in an area, and what has and has not been conserved and therefore depends on known elements of diversity and their mapped occurrences (Scott 1999). This analysis placed more emphasis on abiotic variables based on the argument that the selection of nature reserves should be more strongly influenced by the physical environment than the dynamic biological environment (Hunter *et al.* 1988), and because most of the abiotic variables chosen were known to be correlated with species richness (Boone and Krohn 2000a,b, Nichols *et al.* 1998). In many cases, biotic data such as species richness are not available or complete for an area, while abiotic data often are. In this analysis, the woody plant and terrestrial vertebrate richness is a crude measure of the number of species predicted to occur in each cell and does not account for the habitat available in each cell. There are other ways to measure the representation of species richness for an area. One way would be to divide the number of species potentially occurring in an area by the total number of species predicted to occur as shown by range limits to get a proportion. In this analysis, the results showed the two biophysical regions in southern Maine were the most under-represented for both the abiotic and biotic variables.

Relative threshold levels were used to define under-representation when comparing the range of values in conservation versus non-conservation for each variable class. An advantage to using a relative threshold level is it considers the size of the area in conservation relative to the size of the area in non-conservation. When using a small absolute threshold level (i.e., 2%), large areas with a small percent difference between conservation and non-conservation lands (e.g., 34% vs. 36%) may be considered under-represented; while using a larger threshold level (i.e., 6%), may leave small or rare areas, with a substantial percent difference between conservation and non-conservation lands (e.g., 4% vs. 9%), not considered under-represented. The relative threshold level is a proportion of conservation lands to non-conservation lands and eliminates the problem stated above with absolute differences. For this statewide analysis with these particular variables, the results did not differ greatly whether a relative or absolute difference was used. . However, when conducting representational analyses, it's important to understand the effect that threshold levels have on the variable classes being regarded under-represented.

Representational analyses are also dependent on how much each variable's data is generalized when breaking them into classes. Data can be grouped into arbitrary classes or into classes with some biological significance. Breaking data in classes of biological significance would be useful if such relationships were known. In this case, however, too little was known to justify class definitions on biological relations. Thus, I used arbitrary classes in order to gain a general sense of how conservation lands are representing Maine's natural diversity.

The resolution of the data being analyzed relative to the mean size of the conservation lands should also be considered when conducting representational analyses. Excluding the recent large land purchase by the Maine Chapter of TNC, 92% of the conservation land parcels were smaller than the 1.86 x 1.86 km cell resolution and therefore were not analyzed, however, the absolute amount of the area in conservation decreased by only 0.9% from 5.3% (Krohn *et al.* 1999) to 4.4%. This means the cell resolution of this analysis dropped many of the small conservation lands but did not lose a lot of the area in conservation. A state with a low percentage of its conservation land area in large parcels would require a finer cell resolution than the 1.86-km cell size used here. The average size of conservation lands and the level of fragmentation for an area should be determined before deciding on the cell size used, and in some cases studies might require data being analyzed at multiple resolutions.

When conducting representational analyses, one must understand the effects cell resolution, absolute vs. relative difference, varying threshold levels, and subdivision of the data into classes all have on defining the under-represented landscapes. When the above concerns are properly understood, representational analyses can be a powerful method of assessing how well conservation lands mirror the natural variability of an area. Major advantages of this method for establishing conservation priorities are: (1) it leads towards a system that represents an area's ecological condition; (2) it is readily applied to large areas in a spatially explicit manner; (3) it is based on data that are, or soon will be, readily available in GIS format; and (4) it is flexible given that users can choose to set priorities on all variables (as done above), only the most fundamental variables (in the sense of Hunter *et al.* 1988) or any subset of variables that is biologically justified.

The representational analysis used here has application in other areas where the issues of objectively identifying lands in need of conservation is an issue. Representational analyses have been widely applied in countries including Australia (Bedward *et al.* 1992, Belbin 1993, McKenzie *et al.* 1989), Sweden (Nilsson and Gotmark 1992) and to a lesser extent in North America (Scott *et al.* 2001). Scott *et al.* (2001), in a representational analysis of the nature reserves in the United States, found they are most frequently found at higher elevations and on less productive soils.

Representational analyses do not provide all of the information needed to assess the need for conservation lands. Other factors should be addressed when considering lands to set aside for conservation such as resiliency (how quickly can the set of conservation lands bounce back from disturbance) (Holling and Meffe 1996) and redundancy (the need for more than one type of each land-type in conservation) (Wellnitz and Poff 2001). By first defining the land types that are under-represented and in need of protection, others can more easily design for the addition of these land types with resiliency and redundancy in mind. This analysis is but the first step towards a coordinated strategy of biodiversity maintenance. Once priority areas for conservation are selected, further information should be evaluated, based on field reconnaissance (Scott and Csuti 1997).

LITERATURE CITED

Ando, A., Camm, J., Polasky, S., and A. Solow. 1998. Species distributions, land values, and efficient conservation. *Science* 279:2126-2128.

Baskerville, G.L., and P. Emin. 1969. Rapid estimation of heat accumulation from maximum and minimum temperatures. *Ecology* 50:514-517.

Bedward, M., R.L. Pressey, and D.A. Keith. 1992. A new approach for selecting fully representative reserve networks: addressing efficiency, reserve design, and land suitability with an iterative analysis. *Biological Conservation* 62:115-125.

Belbin, L. 1993. Environmental representativeness: Regional partitioning and reserve selection. *Biological Conservation* 66:223-230.

Boone, R.B. 1997. Modeling the climate of Maine for use in broad-scale ecological analyses. *Northeastern Naturalist* 4:213-230.

Boone, R.B. and W.B. Krohn. 1998a. Maine gap analysis vertebrate data – Part I: distribution, habitat relations, and status of amphibians, reptiles, and mammals in Maine. Part of final contract report to USGS Biological Resources Division, Gap Analysis Program, Moscow, Idaho. 175 pp. plus appendices.

Boone, R.B. and W.B. Krohn. 1998b. Maine gap analysis vertebrate data – Part II: distribution, habitat relations, and status of breeding birds in Maine. Part of final contract report to USGS Biological Resources Division, Gap Analysis Program, Moscow, Idaho. 367 pp. plus appendices.

Boone, R.B. and W.B. Krohn. 2000a. Partitioning sources of variation in vertebrate species richness. *Journal of Biogeography* 27:457-470.

Boone, R.B. and W.B. Krohn. 2000b. Relationship between avian range limits and plant transition zones in Maine. *Journal of Biogeography* 27:471-482.

Brundtland, G.H. (chairperson). 1987. Our Common Future: World commission on environment and development. Oxford University Press, New York, NY. 400 pp.

Chokkalingam, U. 1998. Spatial and temporal patterns and dynamics in old growth northern hardwood and mixed forests of northern Maine. Ph.D. Dissertation, University of Maine, Orono. 95 pp.

Cox, B. and P. Moore. 1993. Biogeography: An ecological and evolutionary approach 5E. Blackwell Science, Inc. Cambridge, MA. 298 pp.

Currie, D.J. 1991. Energy and large-scale patterns of animal- and plant- species richness. *American Naturalist* 137:27-49.

Davis, F.W., J.M. Scott, D.M. Stoms, J.E. Estes, and J. Scepan. 1990. An information systems approach to the preservation of biological diversity. *International Journal of Geographical Information Systems* 4:55-78.

Hepinstall, J.A., S.A. Sader, W.B. Krohn, R.B. Boone, and R.I. Bartlett. 1999. Development and testing of a habitat and land cover map of Maine. Maine Agriculture and Forest Experiment Station, Technical Bulletin 173, University of Maine, Orono. 104 pp.

Holling, C.S., and Meffe, G.K. 1996. Command and Control and the Pathology of natural resource management. *Conservation Biology* 10:328-337.

Hunter, M.L., Jr., G.L. Jacobson, Jr., and T. Webb, III. 1988. Paleoecology and the coarse filter approach to maintaining biological diversity. *Conservation Biology* 2:375-385.

Hunter, M.L., Jr., and P. Yonzon. 1993. Altitudinal distributions of birds, mammals, people, forests, and parks in Nepal. *Conservation Biology* 7:420-423.

Hunter, ML., Jr. 1996. Fundamentals of Conservation Biology. Blackwell Science, Inc. Cambridge, MA. 482 pp.

Irland, L.C. 1996. Wildness and wilderness in the northeastern United States: Challenge for the coming century. *International Journal of Wilderness* 2:27-30,48.

Izakson, O. 1999. Land in the balance: Maine environmentalists, property-rights activists, paper companies battle over public, private ownership. Bangor Daily News, February 27-28, 1999, A1.

Kellett, M.J. 1989. A New Maine Woods Reserve: Options for protecting Maine's northern wildlands. A report by The Wilderness Society, March 1989.

Knight, R.L. 1999. Private lands: The neglected geography. *Conservation Biology* 13:223-224.

Krebs, C.J. 1978. The experimental analysis of distribution and abundance. Harper and Row, New York, NY. 678 pp.

Krohn, W.B., K.D. Elowe, and R.B. Boone. 1995. Relations among fishers, snow, and martens: development and evaluation of two hypotheses. *The Forestry Chronicle* 71:97-105.

Krohn, W.B. and R.D. Kelly, Jr. 1997. A conservation and public lands database for Maine: Project history and database documentation. Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono. 16 pp.

Krohn, W.B., R.B. Boone, and S.L. Painton. 1999. Quantitative delineation and characterization of hierarchical biophysical regions of Maine. *Northeastern Naturalist* 6(2):139-164.

Krohn, W.B., R.B. Boone, S.A. Sader, J.A. Hepinstall, S.M Schaefer, and S.L. Painton. 1999. Maine Gap Analysis – a geographic analysis of biodiversity. Final contract report to USGS Biological Resources Division, Gap Analysis Program, Moscow, Idaho. 120 pp. plus appendices.

Leader-Williams, N., J. Harrison, and M.J.B. Green. 1990. Designing protected areas to conserve natural resources. *Scientific Progress Oxford* 74:189-204.

Maddock, A. and G.A. Benn. 2000. Identification of conservation-worthy areas in northern Zulaland, South Africa. *Conservation Biology* 14:155-166.

Maine Office of GIS (MOGIS). 1997. 1:24,000 Base Layers. Produced by the MOGIS for the Maine GIS Executive Council, 2 CD set (for more metadata information, see http://apollo.ogis.state.me.us).

Maine State Planning Office. 1997. Final Report and Recommendations of the Land Acquisition Priorities Advisory Committee. Submitted to Governor Angus S. King, Jr., November, 1997.

Margules, C.R. 1989. Introduction to some Australian developments in conservation evaluation. *Biological Conservation* 50:1-11.

Margules, C.R., A.O. Nicholls, and M.B. Usher. 1994. Apparent species turnover, probability of extinction and the selection of nature reserves: a case study of the Ingleborough Pavements. *Conservation Biology*, 3:398-409.

McKenzie, N.L., L. Belbin, C.R. Margules, and G.J. Keighery. 1989. Selecting representative reserve systems in remote areas: A case study in the Nullarbor region, Australia. *Biological Conservation* 50:239-261.

McMahon, J.S. 1990. The biophysical regions of Maine: patterns in the landscape and vegetation. M.S. Thesis, University of Maine, Orono. 119 pp.

National Research Council. 1993. Setting Priorities for Land Conservation. Committee for scientific and technical criteria for representative sample of natural diversity acquisition of lands for conservation. National Academy of Sciences, Washington, D.C. 262 pp.

Nichols, W.F., K.T. Killingbeck, and P.V. August. 1998. The influence of geomorphological heterogeneity on biodiversity II: A landscape perspective. *Conservation Biology* 12:371-379.

Nilsson, C. and F. Gotmark. 1992. Protected areas in Sweden: Is natural variety adequately represented? *Conservation Biology* 6:232-242.

Noss, R.F. 1983. A regional landscape approach to maintain diversity. *Bioscience* 33:700-706.

Noss, R.F. 1987. Protecting natural areas in fragmented landscapes. *Natural Areas Journal* 7:2-13.

Pimm, S.L. and J.H. Lawton. 1998. Planning for Biodiversity. *Science* 279:2068-2069.

Plantinga, A.J., T. Mauldin, and R.J. Alig. 1999. Land use in Maine: determinants of past trends and projections of future changes. Res. Pap. PNW-RP-511. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 20 pp.

Pressey, R.L. 1990. Reserve selection in New South Wales: where to form here? *Australian Zoologist* 26:70-75.

Pressey, R.L. 1992. Nature Conservation in Rangelands: lessons from research on reserve selection in New South Wales. *Rangeland Journal* 14:214-226.

Pressey, R.L., C.J. Humphries, C.R. Margules, R.I. Vane-Wright, and P.H. Williams. 1993. Beyond Opportunism: key principles for systematic reserve selection. *Trends in Ecology and Evolution* 8:124-128.

Pressey, R.L. 1994. Ad Hoc Reservations: Forward or backward steps in developing representative reserve systems? *Conservation Biology* 8:662-668.

Pressey, R.L. and S.L. Tully. 1994. The cost of *ad hoc* reservation: A case study in western New South Wales. *Australian Journal of Ecology* 19:375-384.

Pressey, R.L. and K.H. Taffs [In prep]. After representativeness: Additional criteria needed to measure progress in the coverage of protected areas, applied to western New South Wales. Draft provided to Stephanie Painton, University of Maine, Orono, Maine.

Scott, J.M. 1999. A representative biological reserve system for the United States? *Society for Conservation Biology Newsletter* 6:1 - 9.

Scott, J.M. and B. Csuti. 1997. Noah worked two jobs. *Conservation Biology* 11: 1255-1257.

Scott, J.M., F.W. Davis, R.G. McGhie, R.G. Wright, C. Groves, and J. Estes. 2001. Nature Reserves: Do they capture the full range of America's Biological Diversity? *Ecological Applications* 11(4):999-1007.

Soulé, M.E. 1991. Conservation: Tactics for a Constant Crisis. *Science* 253:744–749.

Turner, M.G. 1990. Spatial and temporal analysis of landscape patterns. *Landscape Ecology* 4:21-30.

Wallace, J.M. and P.V. Hobbs. 1977. Atmospheric Science. Academic Press, New York, NY. 467 pp.

Wellnitz, T. and N.L. Poff. 2001. Functional redundancy in heterogeneous environments: implications for conservation. *Ecology Letters* 4:177-179.

Wessels, K.J., S. Frietag, and A.S. van Jaarsveld. 1999. The use of land facets as biodiversity surrogates during reserve selection at a local scale. *Biological Conservation* 89:21-38.

World Resources Institute. 1992. Global biodiversity strategy. World Resources Institute, Washington D.C. 244 pp.

Wright, D.H. 1983. Species-energy theory: an extension of species-area theory. *Oikos* 41:496-506.

Wright, R.G., and P.D. Tanimoto. 1998. Using GIS to prioritize land conservation actions: Integrating factors of habitat diversity, land ownership, and development risk. *Natural Areas Journal* 18:38-44.

CHAPTER 2

A REPRESENTATIVE ANALYSIS OF CONSERVATION LANDS IN SOUTHERN MAINE

INTRODUCTION

One approach to maintaining biodiversity for a landscape is to create a network of conservation lands that represent the full range of natural diversity in a region (Prendergast *et al.* 1998, Scott *et al.* 2001). In such analyses, the goal is to conserve lands that represent examples of all the natural features in a region (Pressey 1992). In Australia and the United States, recent strategies in conservation planning emphasize the need to encompass the range of regional variation in natural environments within a conservation area network (Margules *et al.* 1991, Noss 1983, Pressey and Logan 1994). Selection of conservation lands has tended to be opportunistic and focused on areas with few competing land uses (Pressey 1994), leaving areas with the greatest need for protection unprotected (Margules 1999). This has resulted "in a strong bias favoring species in areas with the least potential for extractive uses" (Pressey and Tully 1994).

The paleoecological record clearly shows that most modern plant communities in North America are temporary assemblages (most less than 8,000 years old), shifting in abundance and distribution through time (Hunter *et al.* 1988). Therefore, designing conservation reserves around where plant and animal species occur is not an efficient way of maintaining biodiversity into the future (Hunter *et al.* 1988, Nichols *et al.* 1998). Conservation reserves should contain a range of environments to allow organisms to adjust their local distribution in response to long term environmental change. For example, if a reserve encompassed a significant gradient of temperature or precipitation, organisms might be able to move within the reserve to adapt to global and regional climate changes (Hunter *et al.* 1988). A coarse filter approach focused primarily on physical environments rather than specific extant communities is a recommended strategy (Hunter *et al.* 1988, Nichols *et al.* 1998). Another advantage of using physical variables over the biotic variables is they can be derived more quickly and cheaply than assessments of the distributions of species (Hunter *et al.* 1988, Pressey and Logan 1994).

A representational analysis will be more meaningful when conducted on relatively homogeneous areas (Leader-Williams *et al.* 1990). Of the five major biophysical regions in Maine (modified from Krohn *et al.* [1999]), the Coastal Plain and Foothills Region (see Figure 2.1) in the southern and central parts of the state, and the Eastern Foothills and Lowlands region in eastern Maine, are the most under-represented by conservation lands (Chapter 1, Table 1.4). Maine Gap Analysis, which was a hot spot versus a representational analysis, found southern Maine in highest need of conservation lands (Krohn *et al.* 1999). Considering both studies together, southern Maine is the region of Maine in greatest overall need of additional conservation lands. In addition, of the 113,310 ha of new urban lands projected to be created in Maine by 2050, 98% (110,880 ha) will be in the state's southern and central counties (Plantinga *et al.* 1999: Table 8). Thus, the Coastal Plain and Foothills Region, hereafter referred to as southern Maine, was the area chosen for this analysis.

Scale plays an important role in the outcome of representational analyses using various land classes or environmental variables (Pressey and Logan 1994). Pressey and Bedward (1991) analyzed 14 Australian studies on representative reserve methods and found that as land classes were defined more finely the percentage represented in reserves declined. Pressey and Logan (1994) found similar results in their study of about 60 regional reserve systems studies. Their study showed the assessments of reserve coverage is dependent upon the level of subdivision of the land classes and the criteria used to define land classes as "reserved" (1994). According to Pressey and Logan (1994), "…finer classes will be more homogeneous biophysically and therefore better targets for reservation if the aim is to maximize the representation of species and their habitats." For these reasons, I analyzed southern Maine using a grid cell size of 94.6 x 94.6 m resolution (versus 1.86 x 1.86 km cell size for the statewide analysis, Chapter 1).

The purpose of this medium-scale analysis is to determine what environmental variables are under-represented by conservation lands in southern Maine. Specific objectives are as follows:

(1) Determine the distribution of under-represented environmental variables, as defined by relative differences on and off conservation lands in southern Maine, and aggregate the under-represented variables and calculate the number of under-represented variables in each cell in southern Maine.

(2) Assess the sensitivity of the under-representation analysis (Objective 1) to the abiotic and biotic variables used, and to the cutoff levels (i.e., thresholds used to define relative under-representation), and to absolute under-representation.

(3) Determine the relationship of the areas most under-represented by conservation lands to the human population under contrasting development scenarios.

This analysis makes the following assumptions: (1) abiotic and biotic variables can be used as measures of landscape variability (Hunter and Yonzon 1993); (2) public conservation lands should represent the natural variation within the landscape (Pressey *et al* 1993); and (3) more focus should be placed on physical environments as habitats for biota than on specific existing communities (Hunter *et al.* 1988, Margules *et al.* 1994).

STUDY AREA

As defined here, southern Maine is approximately 18,902 km^2 or about 22.4% of Maine (Krohn *et al.* 1999) (Figure 2.1). The elevation in this region averages about 88 m, with an average slope of 4 degrees. The flat areas tend to be along the coast, while the steeper gradients are in the western part. There are some isolated coastal mountains in the north end of the region. Mixed forests account for half of the upland vegetation, while fields and deciduous forests make up a large part of the other half (Figure 2.8). Wetlands are abundant and scattered throughout the region, covering approximately 11% of southern Maine (Figure 2.9).

Southern Maine has the warmest climate of Maine's five major regions and the highest mean value of heat accumulation, which is designed to quantify the energy available to organisms (Krohn *et al.* 1999). This region, in turn, has the highest terrestrial vertebrate and woody plant richness of the five regions (Krohn *et al.* 1999). Southern Maine has the highest number of terrestrial threatened and endangered species and is supporting the densest human population (>16 people/km^2 over much of the area), especially along the coast and in major river valleys (Krohn *et al.* 1999). The human population is currently redistributing itself, with people moving out of the cities and

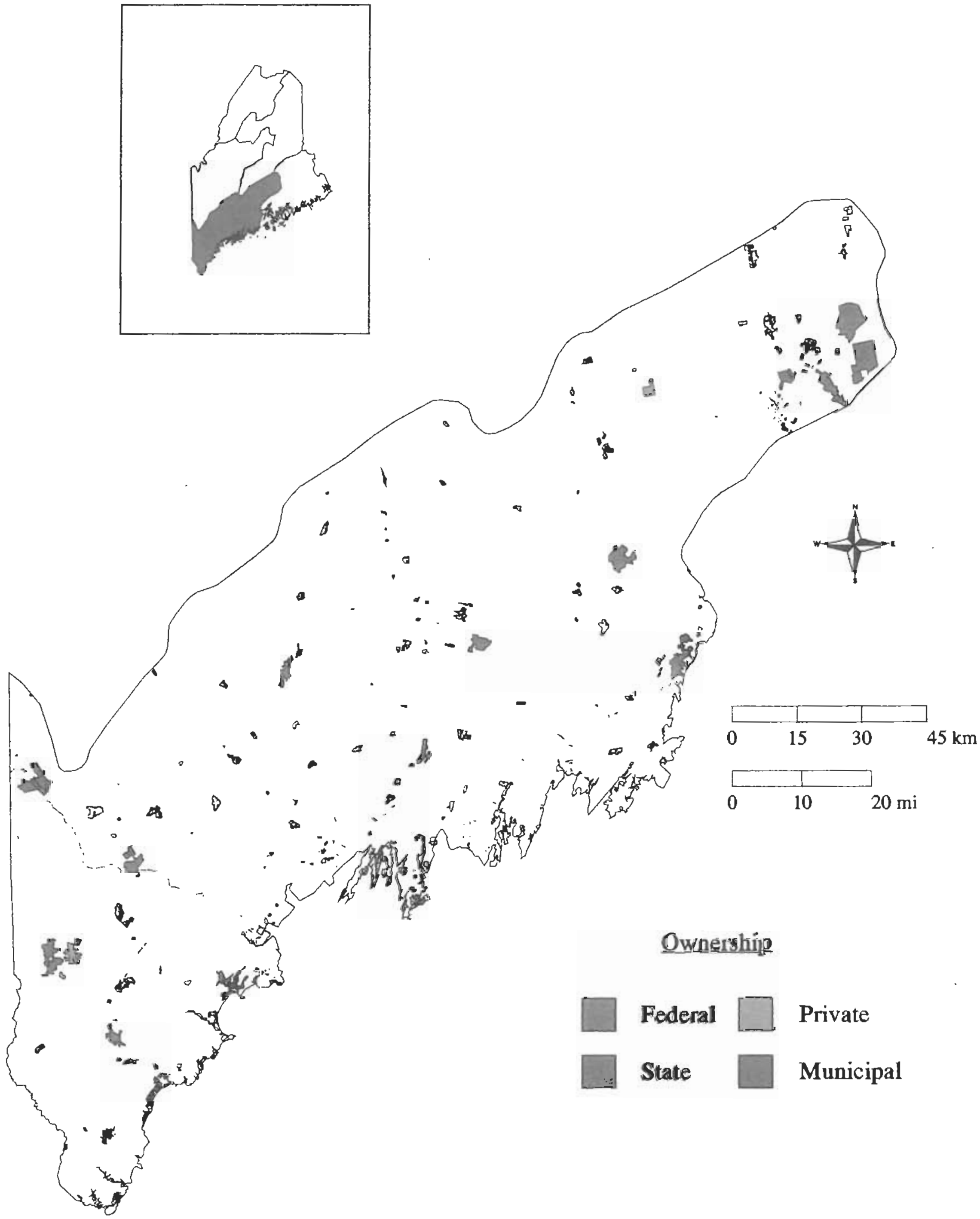


Figure 2.1. Location, ownership, and size of conservation lands analyzed in southern Maine. Location of the Coastal Plain and Foothills Region, in relation to Maine, shown in insert map.

larger towns and into more rural areas of southern Maine (Krohn *et al.* 1998). This sprawl is expected to result in more than 100,000 ha of new urban lands by 2050 (Plantinga *et al.* 1999).

METHODS

Conservation Lands

Currently, less than 3% of southern Maine is in private and public conservation ownership. The Conservation and Public Lands Database (CAPLD; scale = 1:100,000) includes over 120 landowning organizations distributed among federal, state, municipal, and private conservation organizations in Maine. In southern Maine, approximately 15% of these conservation lands are in federal ownership, 67% are owned by the state, 11% are in private ownership, and 6% are in municipal ownership (Figure 2.1). The distribution of conservation lands in southern Maine tends to be clustered along the coast, with fewer in the center and northern sections of the region (Figure 2.1). For the purpose of this research, conservation lands are defined as those parcels in CAPLD that are private or public lands managed primarily for conservation purposes. Examples of included parcels are state Parks, National Parks, National Wildlife Refuges (NWR), Wildlife Management Areas (WMA) and areas owned by the Maine Chapter of The Nature Conservancy (TNC). Examples of parcels in CAPLD excluded in this study are state historic sites, scenic areas, fish hatcheries, cemeteries, recreation parks, schools, and military lands. Coastal islands were also excluded from this research because the ecological factors affecting coastal ecosystems are markedly different than for inland systems.

Table 2.1. Variables used in the representational analysis of southern Maine. All data was analyzed at 94.6 x 94.6 m cell resolution.

Variables	Measure	Source Cell Resolution	Source
Abiotic			
Topography		94.6 m	DEM[a], USGS[b] (1:24,000)
Elevation	m above msl		
Slope	degrees		
Aspect	degrees		
Hydrography		94.6 m	
Rivers	Distance to nearest		DLG[c], USGS[b] (1:24,000)
Distance to coastline	km		
Biotic			
Vegetation and land cover		30 m	Hepinstall *et al.* (1999) (1:100,000)[d]
Upland	ha		
Wetland	ha		

a – DEM = Digital Elevation Model.
b - USGS = United States Geological Survey.
c – DLG = Digital Line Graph.
d – Wetland data, at 1:24,000, came from the U.S. Fish and Wildlife Service's National Wetlands Inventory.

Aspect

Aspect is also an important factor affecting the distribution of vegetation (Cox and Moore 1993). Hepinstall *et al.* (1999) found aspect and slope were related to the distribution of vegetation. For example, a higher percentage of deciduous forests were on eastern and southern facing slopes than on flat areas, while coniferous-dominated and mixed classes were more evenly distributed across slopes. Boone (1996) calculated aspect values (in degrees) from the Maine DEM. Because aspect is a circular measure with 0° and 359° values similar, Boone (1996) placed them into categories which were as follows: 0 = flat, 1 = northeast, 2 = east, 3 = southeast, 4 = south, 5 = southwest, 6 = west, 7 = northwest, 8 = north.

Distance to Coastline

In Maine, climate at a site and its distance to a coastline is related. In summer, the air over landmasses tends to be warmer than air over large water bodies and in winter the relation is opposite (Wallace and Hobbs 1977). This relationship has been observed in Maine during winter when weather forecasts predict snow inland and rain along the immediate coast (Boone 1997). Ollinger *et al.* (1995) noted areas 20 km or less from the coastline were not representative of areas further inland, therefore, could not be included in models. This was found to be true in Maine because stations reported cooler weather in summer and warmer weather in winter (Boone 1997). Using a GIS function that measures the Euclidean distance from each cell to the coastline, the distance to coastline variable was developed and clipped to the extent of southern Maine.

Distance to Nearest River

Rivers and waterways are important ecologically and provide benefits to the public and the environment including water resources, wildlife habitat, and recreation. Data for statewide rivers were originally modified from USGS Digital Line Graphs (DLG) maps (1989) (scale = 1:100,000) by the Maine Office of GIS (MOGIS). The MOGIS attributed the double line stream features from the DLG's as rivers (MOGIS 1997). I extended the rivers to the point where they opened into a bay. I converted the river data into a grid with a 94.6 x 94.6 m cell size and calculated the distance from every cell in southern Maine to the nearest river. In order to determine if areas close to rivers were represented on conservation lands I grouped the distances to the nearest river into the following classes: 1 – 500 m, 500 – 1,000 m, 1,000 – 1,500 m, and > 1,500 m. The representation of distances greater than 1,500 m on conservation versus non-conservation was not analyzed.

Upland and Wetland Vegetation

Wetlands hold a high number of vertebrates (Krohn *et al.* 1998) and provide public benefits such as habitat and flood control. The upland and wetland vegetation classes investigated for this analysis were modified from the vegetation and land cover map of Maine. The vegetation and land cover map of Maine was developed using Landsat-Thematic Mapper satellite imagery, along with ancillary GIS data (e.g., U.S. Fish and Wildlife Service National Wetlands Inventory [NWI] maps). Supervised, unsupervised, and hybrid approaches of image classification were used to delineate 37 different vegetation and land cover types in 1993 (Hepinstall *et al.* 1999), which I simplified, for ease of analysis, into seven upland (see Figure 2.8A) and five wetland vegetation types (see Figure 2.9A).

Variable Analyses

Each environmental variable was spatially analyzed by conservation lands versus non-conservation lands on a grid basis, using ArcGrid, a module of ARC/INFO Version 7.2 (Windows NT) (Environmental Systems Research Institute, Redlands, CA, USA; use of trade names does not imply endorsement). GIS was used to combine each variable with the conservation and non-conservation land grids and display the number of cells that were in a specific range of values for each variable. For example, the elevation variable between 0 and 50 m has 18,292 cells in conservation lands and 500,029 cells in non-conservation lands. Then, the percent of cells within conservation lands and non-conservation lands were calculated and compared for each range of each variable. The relative difference between conservation and non-conservation lands was obtained by dividing the percent in conservation by the percent in non-conservation. Initially, three levels of representation labeled the differences, which were as follows: (1) Under-represented – a variable's range of values that occurs more frequently on non-conservation lands than conservation lands (relative difference ≤ 0.66); (2) Well-represented – a variable's range of values that occurs within roughly the same proportion on both conservation and non-conservation lands (relative difference between 0.66 and 1); and (3) Over -represented – a variable's range of values that occurs in a higher proportion on conservation than non-conservation lands (relative difference > 1).

Aggregated Variable Analysis

For each variable, every cell was either assigned a '1' if it was under-represented or a '0' if it was over- or well-represented. The resulting grids for each variable were added together using ArcGrid and displayed on a map to show the areas with high numbers of under-represented variables. The cells with high numbers of under-represented variables are presumed to be in need of conservation if the full range of the state's natural diversity is to be protected.

Representational Types

Calculating the relative difference between the amount of the land in conservation versus non-conservation is one way to study the difference. Another way is to directly compare the percents by subtracting one from the other (i.e., absolute difference). To determine the difference between relative and absolute differences between conservation and non-conservation lands, the absolute difference was calculated for each variable class by subtracting the % in conservation by the % in non-conservation.

conservation lands and non-conservation lands, the absolute difference was calculated for each variable class by subtracting the % in conservation by the % in non-conservation.

Threshold Analyses

Due to the subjective nature of placing the relative differences into classes of representation (i.e., under, well, and over), it is important to understand the robustness of these classes. The relative differences were grouped into three classes of threshold levels: 0 – 0.33, 0.33 – 0.66, and 0.66 – 0.99. After calculating the absolute difference, I placed the variables into three classes of 2%, 4%, and 6% threshold levels. Then, a comparison could be made between the absolute and relative differences and the threshold levels used.

Road Density Analysis

Southern Maine has the highest human population density of Maine's major biophysical regions (Krohn *et al.* 1999). Assuming the human population continues to expand from cities and towns, then areas close to them are more likely to be developed before more remote locations (Wright and Tanimoto 1998). I used road density to indicate the location of cities and towns. Road data were obtained from the USGS Digital Line Graph (DLG) 1:24,000-scale road data. Road classes 1 through 4, consisting of interstate, primary, secondary, and improved roads were converted into a grid with 30 m cell size. I calculated the sum (in km) of roads per km^2 then grouped the cells into 3 classes of density (i.e., low, medium, and high) by comparing the grid to the Maine Atlas and Gazeteer (1989) (Figure 2.2). I analyzed the distance from the high-priority area cells using the relative difference to the cells with high road density. The high-priority areas close to high road density have a higher risk of being developed and were labeled "vulnerable."

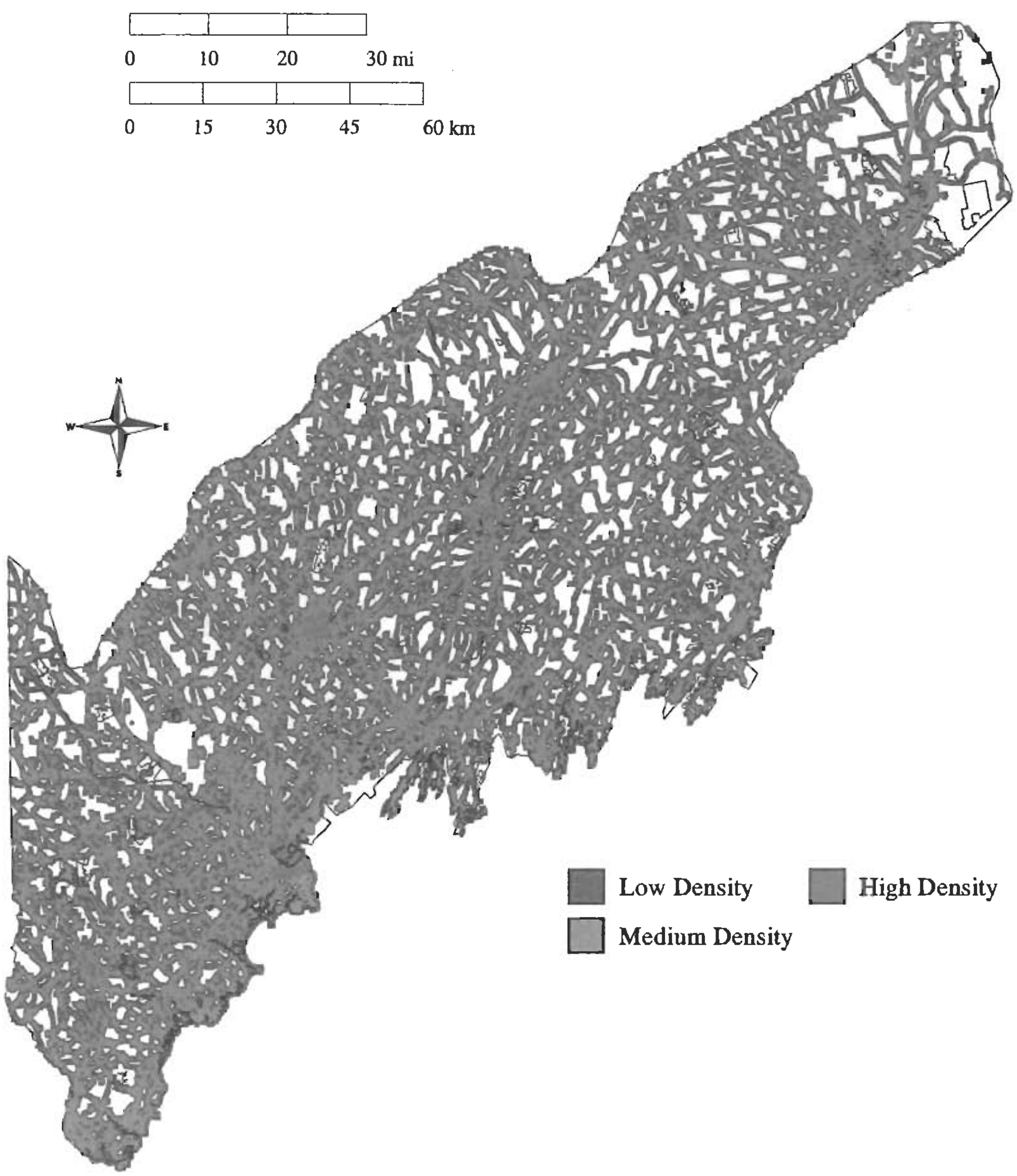


Figure 2.2. Road density cells grouped into 3 classes of density (i.e., high, medium, and low) with a 94.6 x 94.6 m cell size.

RESULTS

Variable Analyses

Approximately 70% of southern Maine is between 50 and 200 m above mean sea level (msl), and about 26% of the region is less than 50 m (range: 0 to 550 m). The range 0 to 50 m is over-represented by conservation versus non-conservation lands (33.4% vs. 24.6%), while 51 to 200 m is well-represented (61% vs. 71%) (Figure 2.3A). The range 401 to 450 m was under-represented with 0.01% in conservation and 0.03% in non-conservation (Figure 2.3A). The under-represented elevations are located in a few places along the northwest portion of southern Maine (Figure 2.3B).

The degree of slope ranges from 0 to 153 in southern Maine, with approximately 52% of the region between 0 and 2 degrees. Degrees of slope less than 2 are over-represented by conservation lands (66.2% vs. 51.4%) and 3 degrees is well-represented. (18.2% vs. 25.8%) (Figure 2.4A). Degrees of slope between 4 and 7 are under-represented by conservation lands. The under-represented areas of slope are scattered throughout the region (Figure 2.4B).

Approximately 19% of southern Maine is flat. The southeast and west facing slopes are under-represented on conservation lands (Figure 2.5A). Flat, east, and northwest facing slopes are well-represented, while north, northeast, south, and southwest facing slopes are over-represented (Figure 2.5A). The under-represented aspect classes are seen in areas with more topographic relief and are distributed across the region (Figure 2.5B).

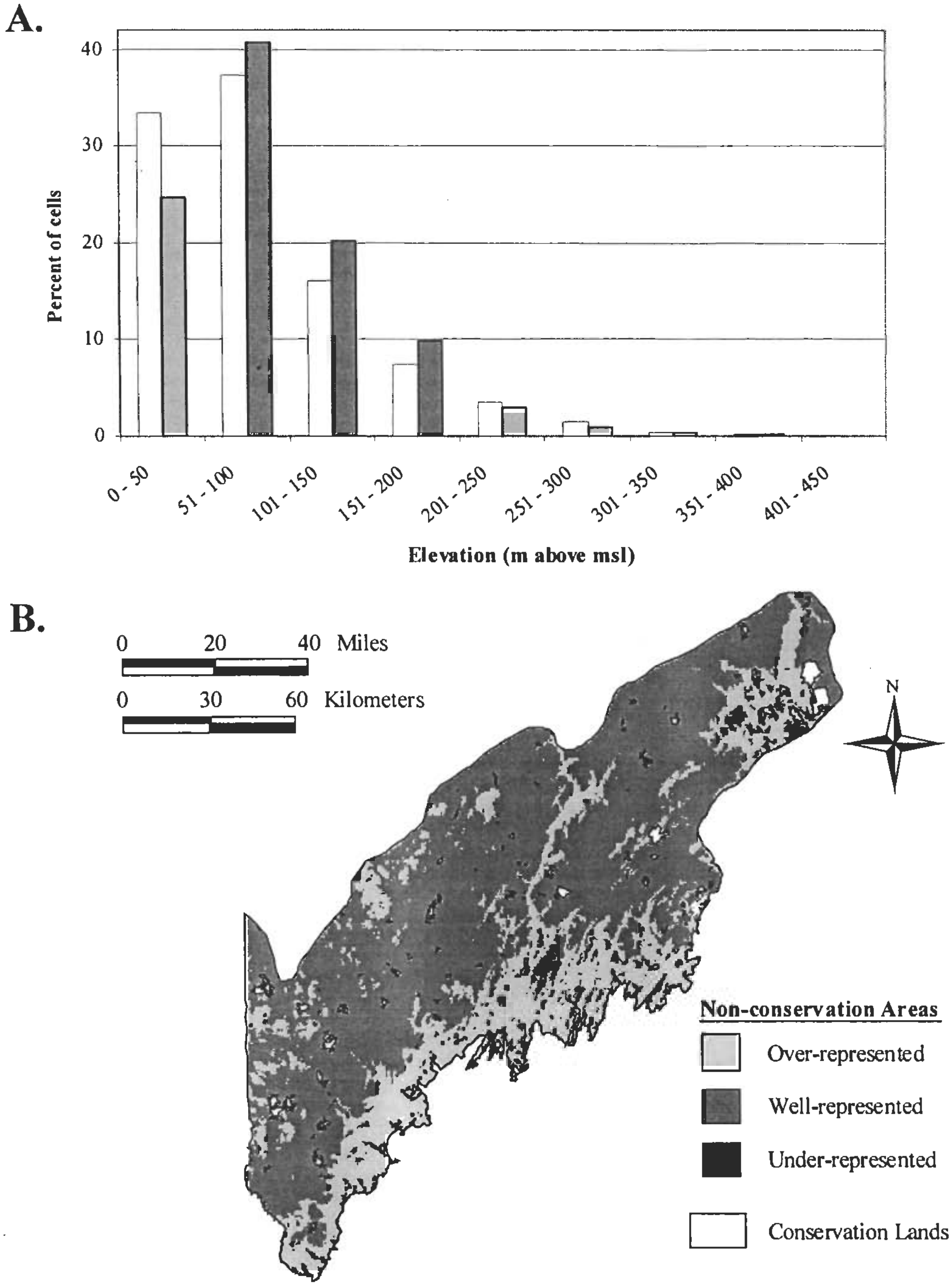
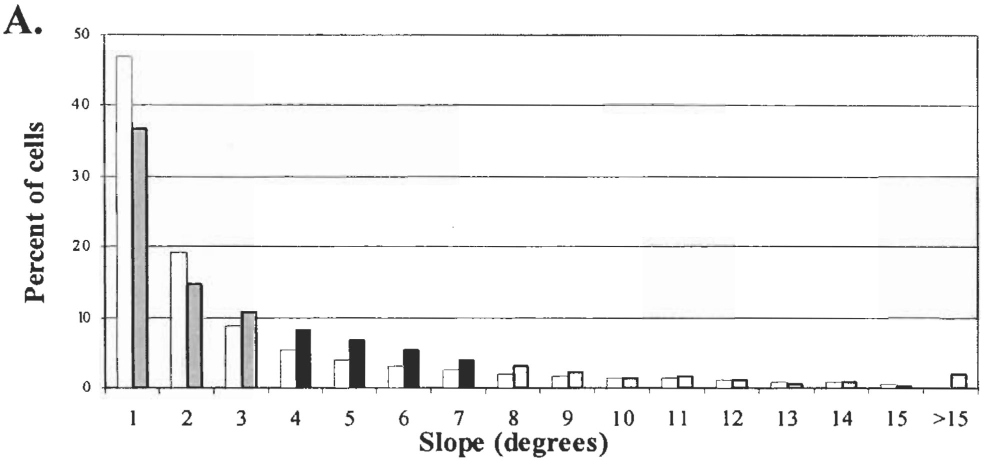


Figure 2.3. Distribution of elevation (m above msl) across southern Maine by conservation and non-conservation areas (**A**), and the representativeness of elevation on non-conservation areas defined by a relative difference (**B**).

A.



B.

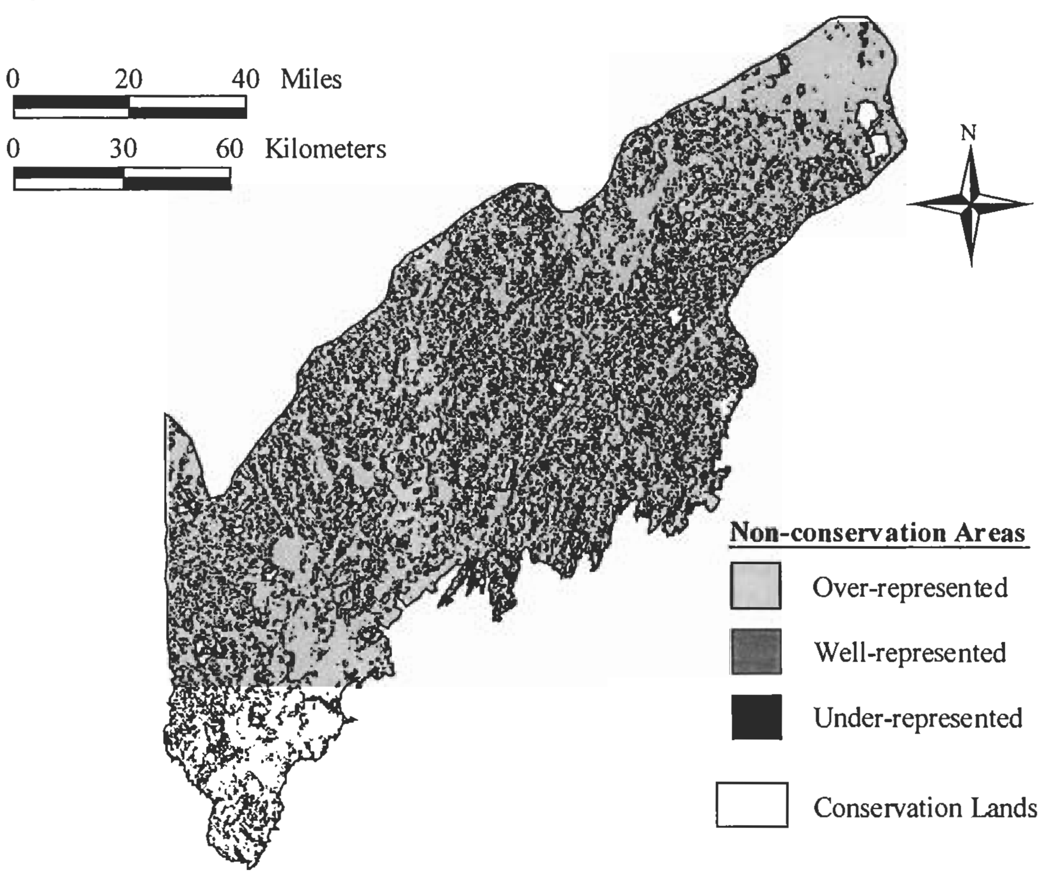


Figure 2.4 Distribution of slope (degrees) across southern Maine by conservation and non-conservation lands (**A**), and the representativeness of slope on non-conservation lands defined by relative differences (**B**).

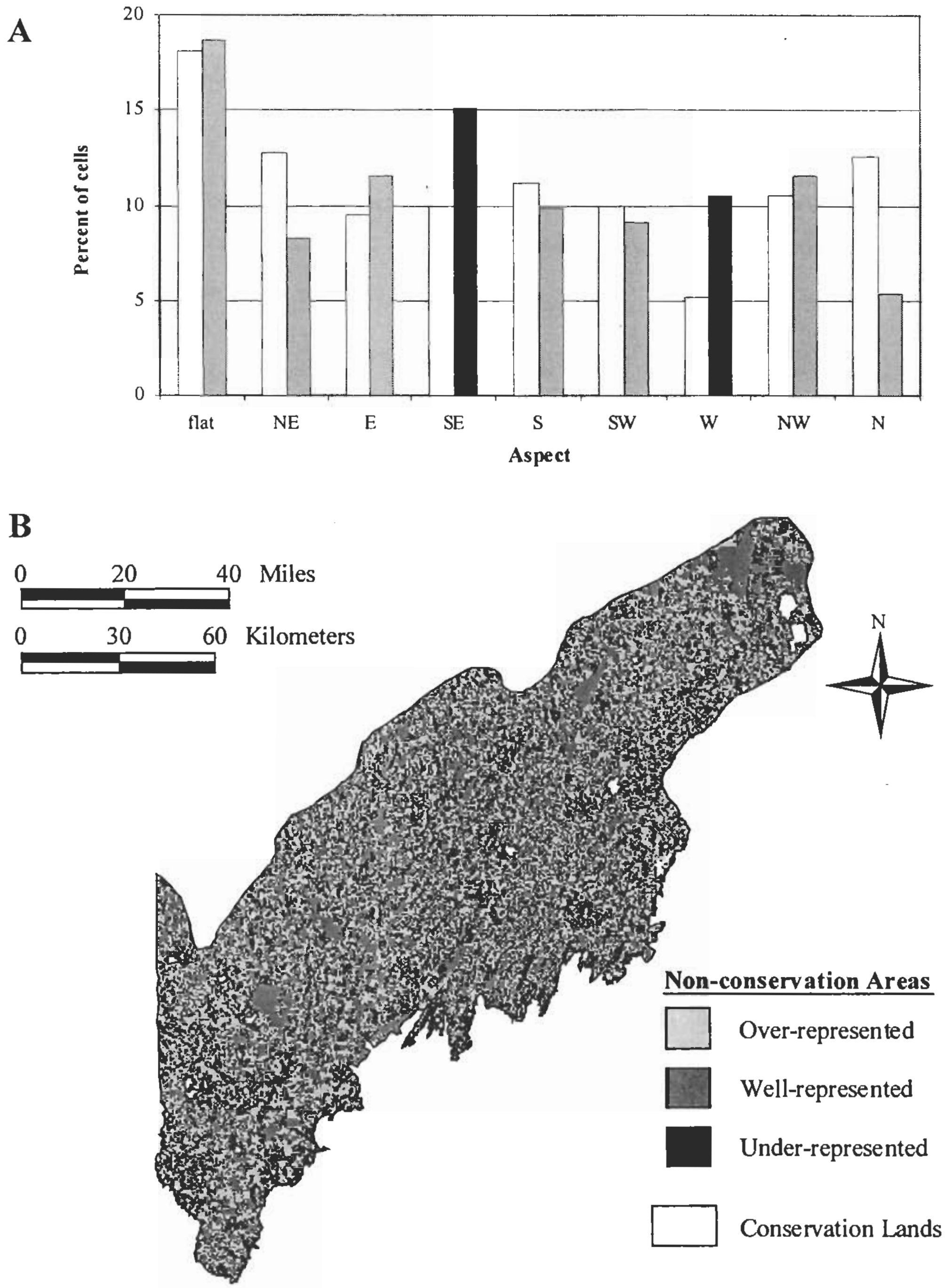


Figure 2.5. Distribution of aspect across southern Maine by conservation and non-conservation areas (**A**), and the representativeness of aspect on non-conservation areas defined by a relative difference (**B**).

The distances between 0 and 500 m to the nearest river were highly over-represented by conservation lands with 35% in conservation and 6.7% in non-conservation and a relative difference of 5.1 (Figure 2.6A). The distances between 500 and 1,500 m were also over-represented (Figure 2.6A).

The range 20,001 to 30,000 m from the coastline are under-represented (9% vs. 15%), along with the range 50,001 to 80,000 m (12% vs. 23%) (Figure 2.7A,B). Conservation lands in southern Maine are over-representing areas within 10,000 m to the coast and are well-representing areas between 10,000 and 20,000 m to the coast (Figure 2.7A,B).

Mixed forests represent about 51% of upland vegetation types, while deciduous types represent approximately 16% and coniferous 8% of upland types (Figure 2.8A). Crops and early successional upland vegetation types were under-represented in this region (Figure 2.8A,B). Mixed and coniferous upland types were well-represented, while deciduous, and alpine tundra/rock outcrop types were over-represented (Figure 2.8A,B).

Of the wetlands in southern Maine, which comprise 11% of the region, 54% are forested wetlands (Figure 2.9A,B). Forested and shrub wetlands are well-represented by conservation lands, while emergent aquatic bed wetlands and peatlands are over-represented on conservation lands (Figure 2.9A,B). Shoreline and mudflats are under-represented by conservation lands (2% vs. 3%) and are located along the coast (Figure 2.9A,B).

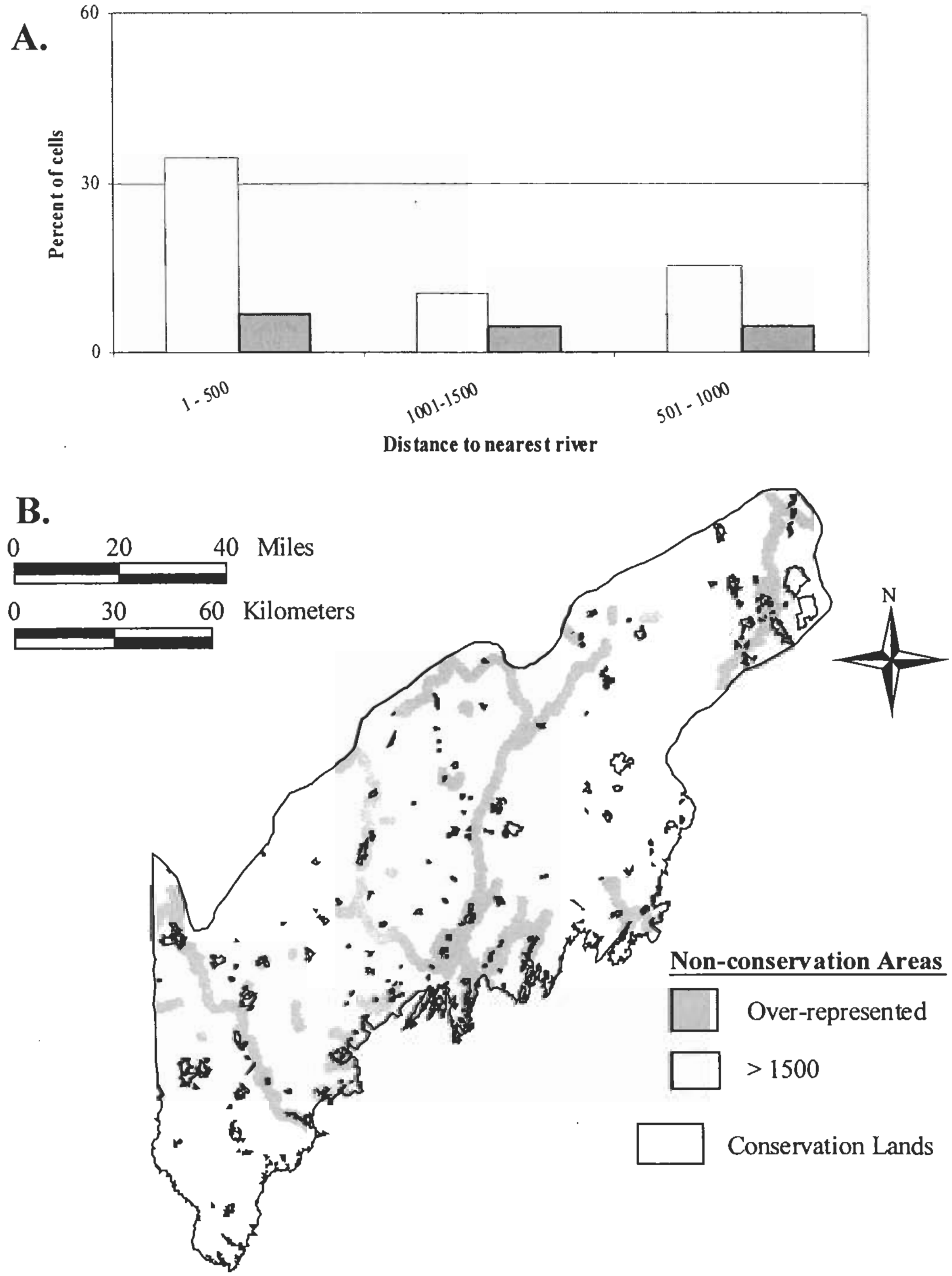
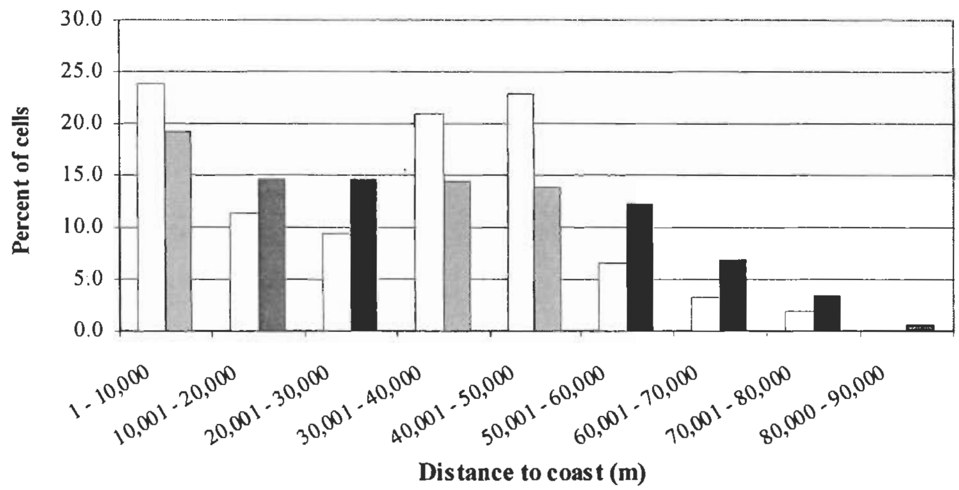


Figure 2.6. Distribution of rivers across southern Maine by conservation and non-conservation areas (A), and the representation of the distance to rivers on non-conservation areas defined by a relative difference of 0.5 (B).

A.



B.

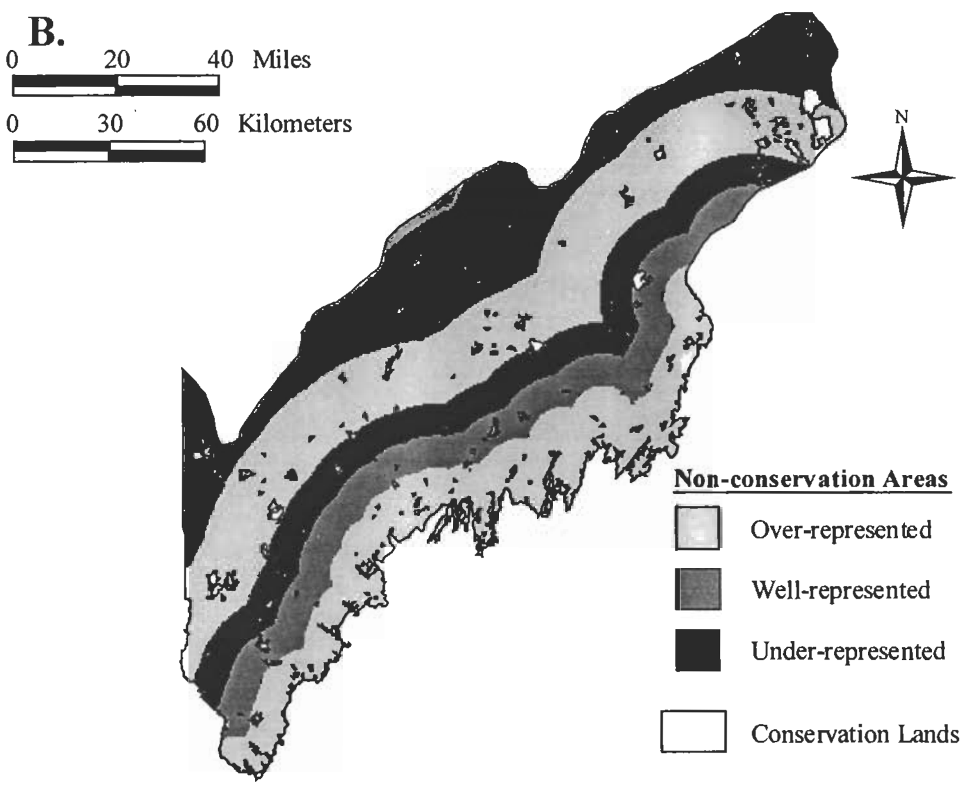
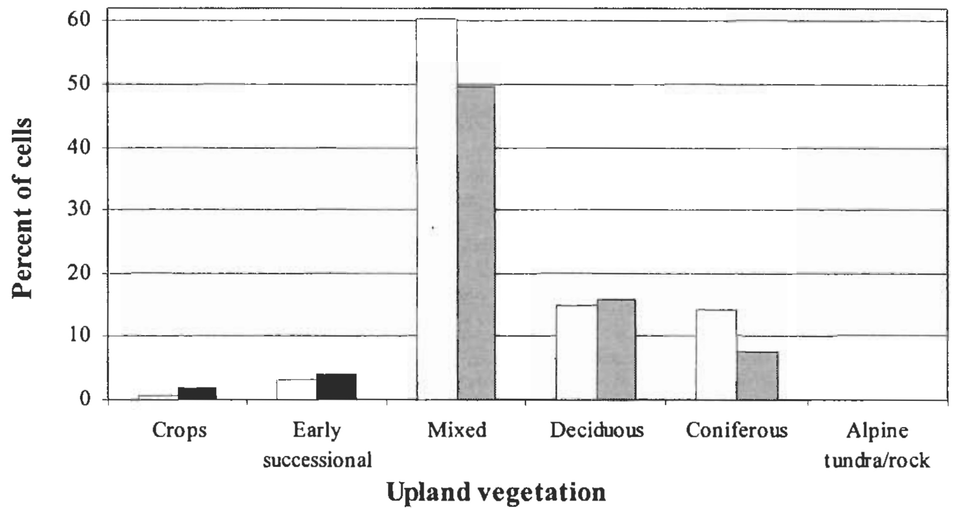


Figure 2.7. Distribution of coastline across southern Maine by conservation and non-conservation areas (**A**), and the representativeness of coastline on non-conservation areas defined by a relative difference (**B**).

A.



B.

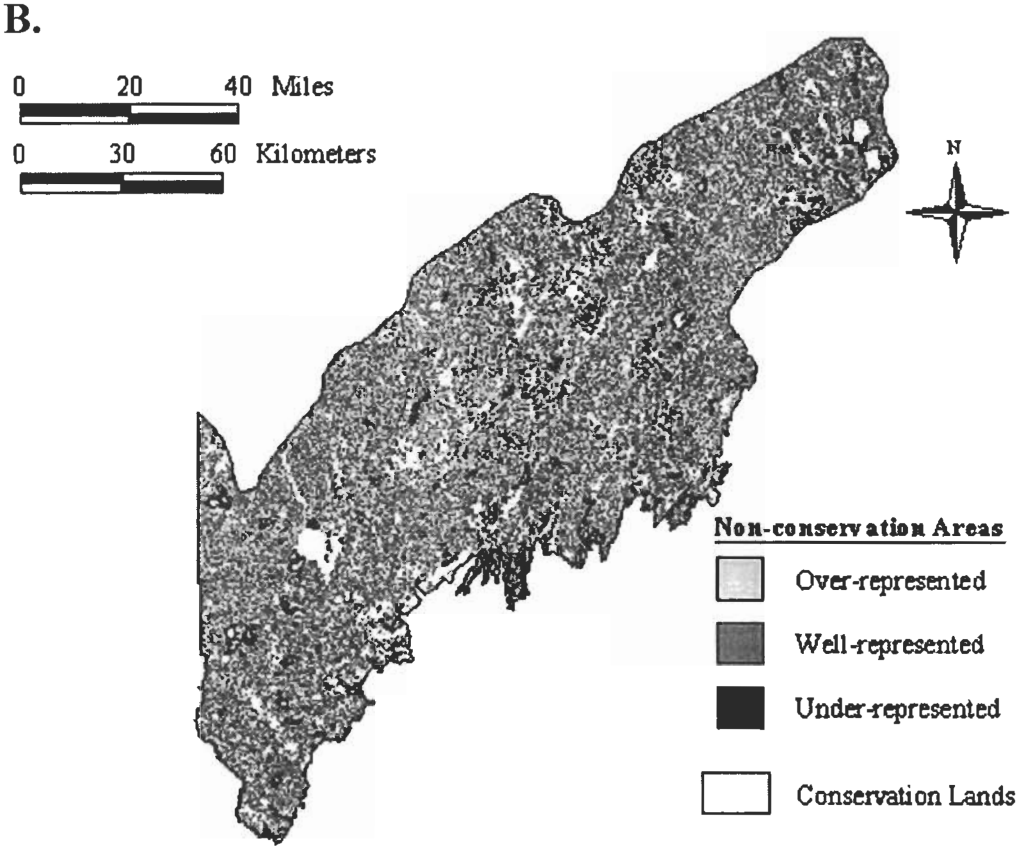
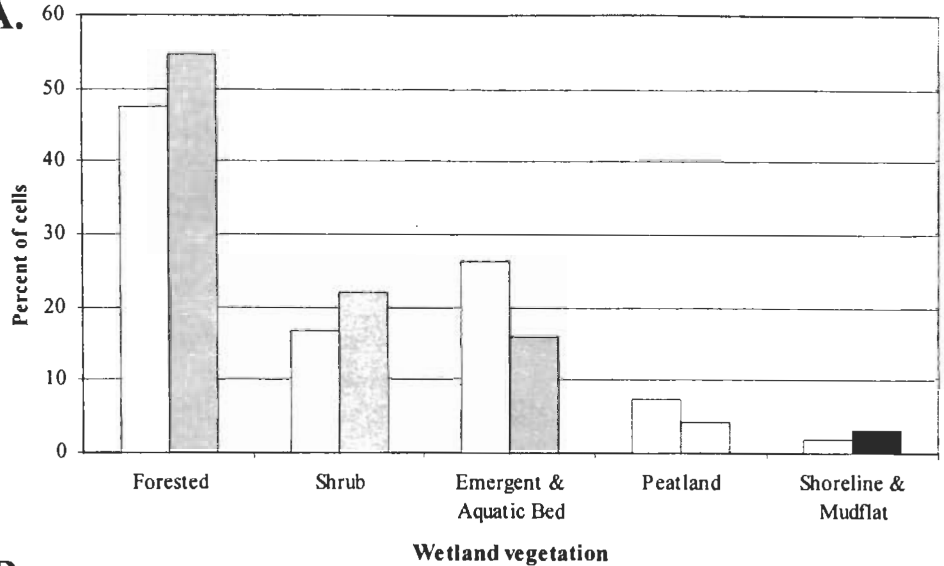


Figure 2.8. Distribution of upland vegetation classes across southern Maine by conservation and non-conservation areas (**A**), and the representativeness of upland vegetation on non-conservation areas defined by a relative difference (**B**).

A.



B.

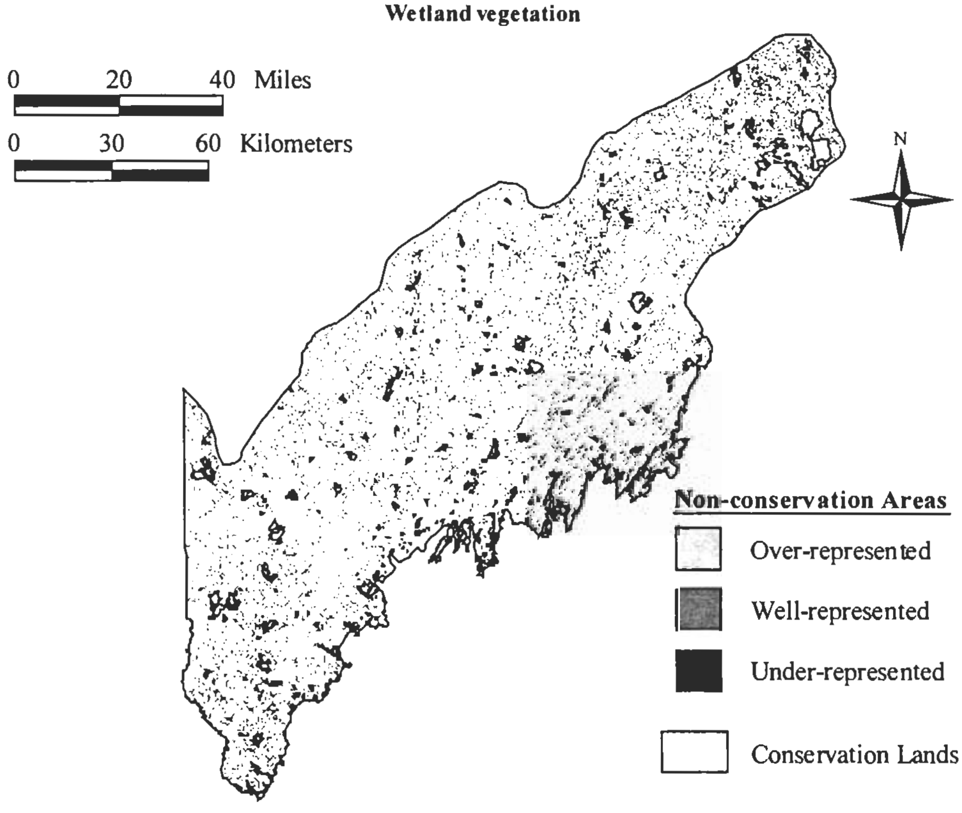


Figure 2.9. Distribution of wetland vegetation classes across southern Maine by conservation and non-conservation areas (**A**), and the representativeness of wetland vegetation on non-conservation areas defined by a relative difference (**B**).

Aggregated Variable Analysis

The areas with high numbers of under-represented variables when aggregated together, hereafter referred to as high-priority areas, were more clustered in the central and northern sections of the region (Figure 2.10). There were very few high-priority areas along the coastline (Figure 2.10). This pattern corresponds with the topographical variables, for example, elevation between 0 and 50 m were over-represented by conservation lands and are mainly along the coastline. This pattern also corresponds to slope and aspect because the most topographic relief is found inland rather than on the coast. The areas with a distance of 30,001 to 60,000 m from the coastline heavily influence the geographical pattern of the high-priority areas as well. There was a range of under-represented variables from 0 to 4. A mean value of 0.9 was calculated by adding the aggregated scores per cell and dividing the total number of cells in southern Maine and a mean of 0.9.

Threshold Analyses

The effects of using a relative difference with a threshold level of 0.66 to define the under-representation of the variable classes was assessed by comparing the absolute difference with three threshold levels (i.e., 2, 4, and 6 %). The results were very sensitive to the absolute threshold levels used illustrating there was not a great difference between the percents in conservation compared to the percents in non-conservation for many variable classes (Table 2.2). For example, there were no elevation classes under-represented with 2%, but 401 – 500 m was under-represented with 4%, and 51 – 100 m was under-represented with 6% (Table 2.2). Similar variable classes were found under-

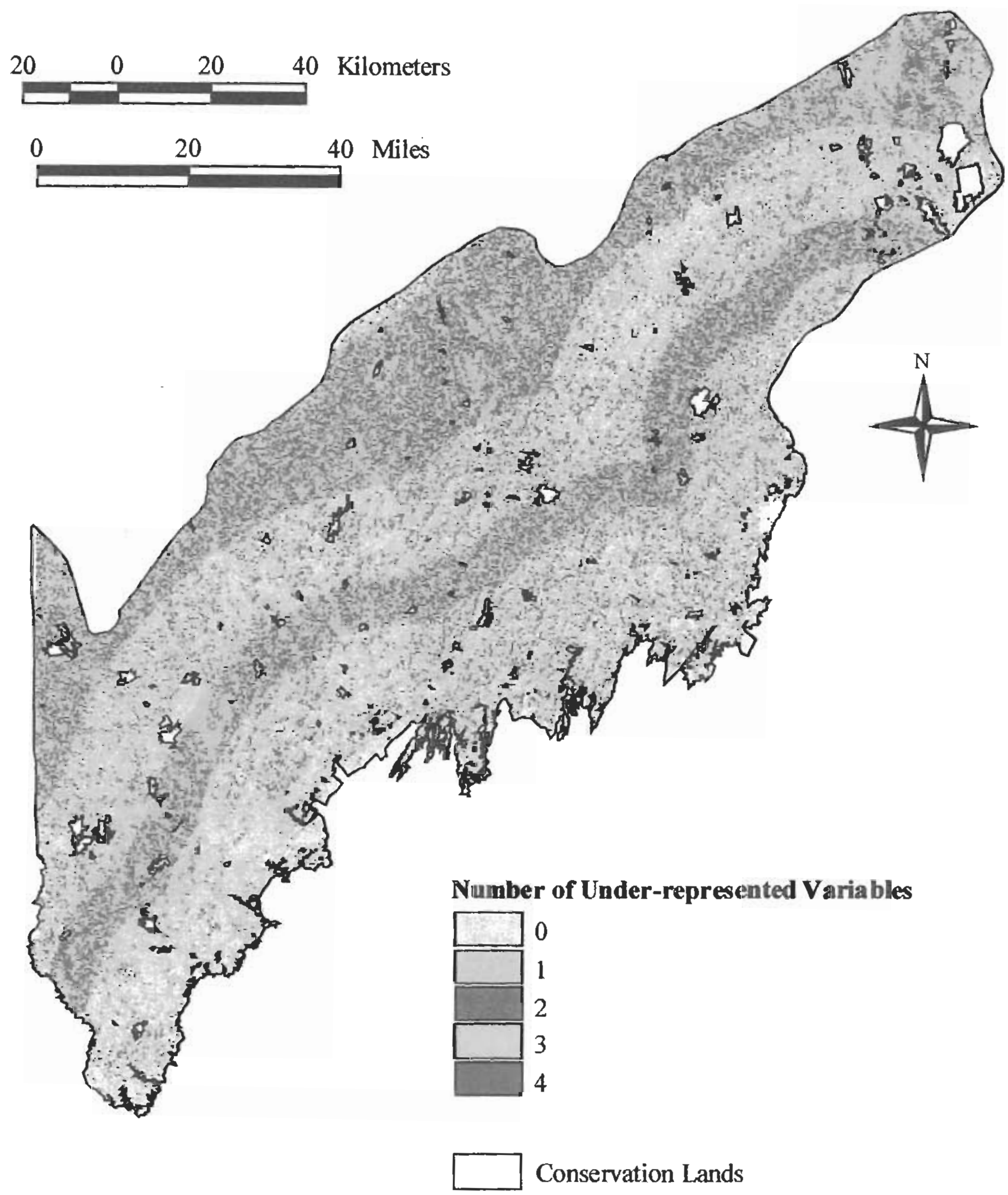


Figure 2.10. Under-represented cells (94.6 x 94.6 m) aggregated for seven environmental variables with a 2% threshold level shown on non-conservation lands in southern Maine.

Table 2.2. Comparison of variable classes under-represented by conservation lands using relative threshold levels versus absolute threshold levels.

Variable Type (under-represented)	Relative Threshold Levels[a]			Absolute Threshold Levels[b]		
	0 - 0.33	0.33 - 0.66	0.66 - 0.99	2%	4%	6%
Elevation (m above msl)	none	401 - 500	51 - 100	none	401 - 500	51 - 100
Slope (angle degrees)	none	4 - 7	3, 8 - 12	none	4 - 7	3, 8 - 12
Aspect (degrees)	none	W, SE	flat, E, NW	none	W, SE	flat, E, NW
Distance to Coast (m)	none	20,000 - 30,000; 50,000-80,000	10,000 - 20,000	none	20,000 - 30,000; 50,000-80,000	10,000 - 20,000
Distance to Rivers (m)	none	1 - 10,000	none	16,000 - 20,000	12,000 - 16,000	2,001 - 6,000
Upland landcover classes	none	Crops, Early-Successional	Mixed, Coniferous	none	Crops, Early Successional	Mixed, Coniferous
Wetland landcover classes	none	Shoreline & Mudflat	Forested, Shrub	none	Shoreline & Mudflat	Forested, Shrub

[a] - Relative difference calculated by dividing the percent in conservation by the percent in non-conservation.

[b] - Absolute difference calculated by subtracting the percent in conservation by the percent in non-conservation.

represented when comparing all the relative and absolute difference threshold levels (Table 2.2).

Road Density Analysis

The distance of each high-priority area cell identified using a relative difference threshold of ≤ 0.66, was measured to high road density cells. The distance from high-priority areas to cells with a high density of roads ranged from 0 to 40 km. First, a frequency distribution of the distances was created and 4 km and 9 km were natural breaks in the data. Next, the high priority areas were divided into 4 ranks according to the number of under-represented variables and their proximity to the high road density areas (i.e., threat).

The high priority areas with ≥ 3 under-represented variables that were within 4 km to high road density areas were given a rank of 1 and are the most threatened by development (Figure 2.11). The high priority areas with ≤ 2 under-represented variables within 4 km to high road density areas were given a 2 (Figure 2.11). The high priority areas with ≥ 3 under-represented variables that were between 4 and 9 km to the high road density areas were given a 3, followed by a '4' given to the high priority areas with ≤ 2 under-represented variables within 4 and 9 km (Figure 2.11).

DISCUSSION

This representational analysis of southern Maine showed areas of high elevation (401 – 450 m above msl), mid to high degrees of slope (4 – 7), southeast and west-facing slopes, and early-successional, crop, and shoreline and mudflat landcovers were under-represented. In the statewide representational analysis (Chapter 1), which was

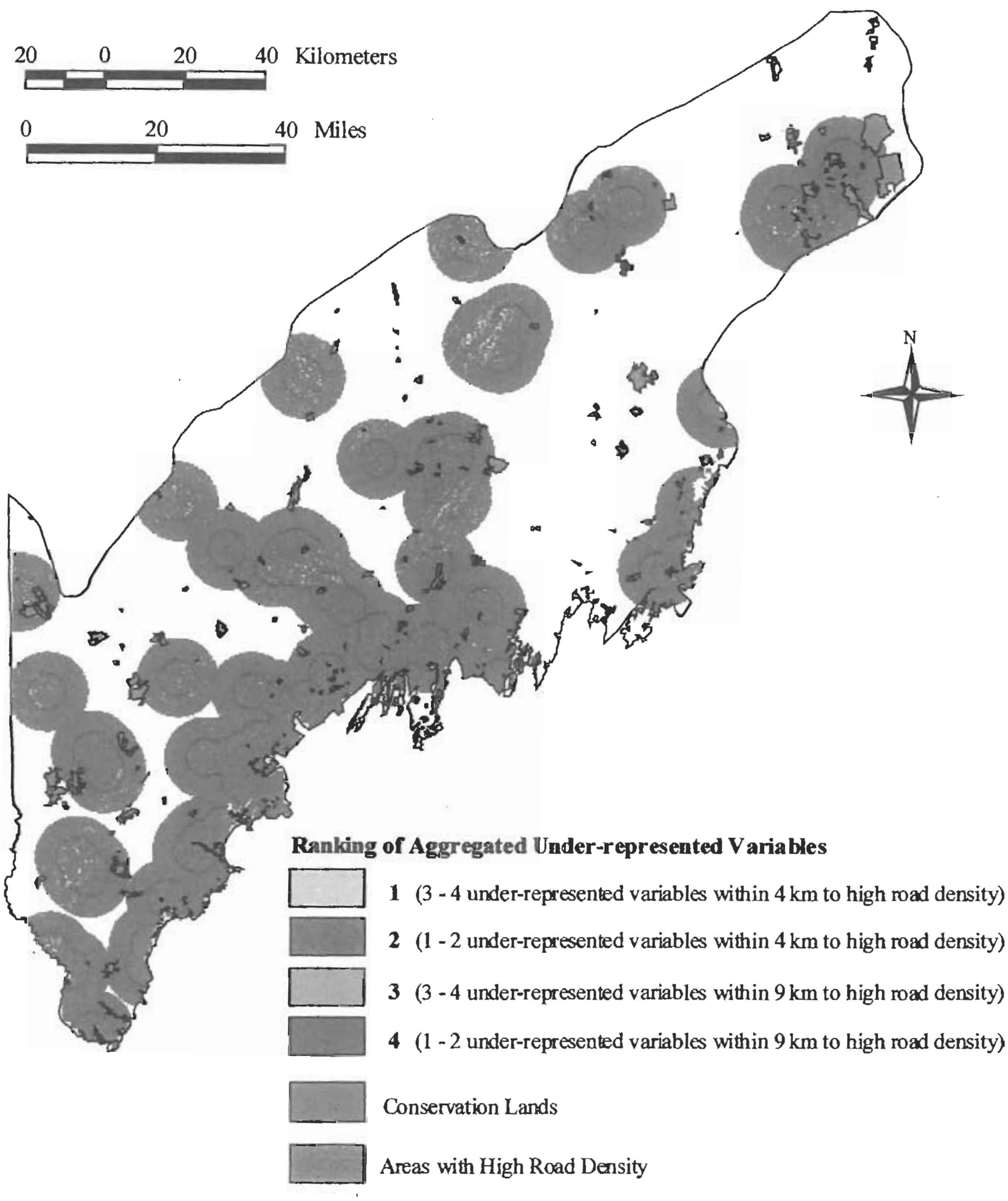


Figure 2.11. Aggregated under-represented variables ranked according to their closeness to high road density cells.

conducted at a coarser resolution (1.86 x 1.86 km), the climate variables were under-represented in southern Maine, with the exception of areas adjacent to the coastline; while the southern Maine analysis analyzed a distance to coastline variable (directly related to climate) and also showed under-representation with the exception of the areas adjacent to the coastline.

Many factors affect the result of representational analyses including: (1) type of representation measured (i.e., absolute vs. relative difference); (2) degrees of under-representation (i.e., threshold levels); (3) the generalization of the variable's values into classes; and (4) cell resolution. In southern Maine, the results were sensitive to varying threshold levels as could be seen by the number of under-represented variables within each relative difference threshold level. The relative difference of 0 – 0.33 showed zero under-represented variables, the 0.33 – 0.66 relative differences showed 4, and the 0.66 – 0.99 relative differences showed 6. The reason for this is because there was not a great difference between the percent in conservation compared to the percent in non-conservation in this analysis. When comparing the results of this analysis to Chapter 1 for southern Maine, the cell resolution did not seem to greatly change the variable classes found under-represented. I did not examine the generalization of variable values into different classes and the effects on the results in this analysis.

There are other factors, such as consideration of aesthetic, recreational, and wilderness concerns, that are not addressed when using a representational analysis and go beyond the objectives of this research. This analysis makes the assumption that a representative sample of natural diversity is the goal of the state of Maine when purchasing more public lands. Another assumption is that ecological knowledge is complete. Scientific studies will continue to expand our knowledge of ecological patterns, while, simultaneously there will be ever-increasing land-use changes. Studies of an area's contribution to a biodiversity goal or target can be measured with the data that are available, and recommendations can be made to policymakers, which is better than no recommendations being made at all.

A method that incorporates the effects of urban sprawl into land conservation planning is possible. Using spatially explicit data on sprawl in southern Maine (i.e., Krohn *et al.* 1999:Figure 1b), one could locate those highest ranking potential conservation lands based on their aggregated scores, size, and closeness to the towns experiencing high rates of sprawl. In short, planners could take many approaches to using the data presented here. One issue this analysis raises is high-priority areas close to human population centers (i.e., cities and towns) should be made a top priority for conservation acquisition or those areas at a greater distance. On average, these lands close to cities and towns will be more expensive than more remote undeveloped lands. In such cases, limited conservation dollars might be better spent on areas at a greater distance in order to get more acres per dollar. This will ultimately be a value judgment the public and policymakers must make.

LITERATURE CITED

Bedward, M., R.L. Pressey, and D.A. Keith. 1992. A new approach for selecting fully representative reserve networks: addressing efficiency, reserve design, and land suitability with an iterative analysis. *Biological Conservation* 62:115-125.

Boone, R.B. and W.B. Krohn. 2000a. Partitioning sources of variation in vertebrate species richness. *Journal of Biogeography* 27:457-470.

Boone, R.B. and W.B. Krohn. 2000b. Relationship between avian range limits and plant transition zones in Maine. *Journal of Biogeography* 27:471-482.

Burnett, M.R., P.V. August, J.H. Brown, Jr., and K.T. Killingbeck. 1998a. The influence geomorphological heterogeneity on biodiversity, I. A patch-scale perspective. *Conservation Biology* 12:363-370.

Burnett, M.R., P.V. August, J.H. Brown, Jr., and K.T. Killingbeck. 1998b. The influence geomorphological heterogeneity on biodiversity, II. A landscape-scale perspective. *Conservation Biology* 12:371-379.

Chokkalingam, U. 1998. Spatial and temporal patterns and dynamics in old growth northern hardwood and mixed forests of northern Maine. Ph.D. Dissertation, University of Maine, Orono. 95 pp.

Cox, B. and P. Moore. 1993. Biogeography: An ecological and evolutionary approach 5E. Blackwell Science, Inc. Cambridge, MA. 298 pp.

Franklin, J.F. 1992. Preserving biodiversity: species, ecosystems, or landscapes? *Ecological Applications* 3:202-206.

Hepinstall, J.A., S.A. Sader, W.B. Krohn, R.B. Boone, and R.I. Bartlett. 1999. Development and testing of a vegetation and land cover map of Maine. Maine Agriculture and Forest Experiment Station, Technical Bulletin 173, University of Maine, Orono. 104 pp.

Hunter, M.L., Jr., and P. Yonzon. 1993. Altitudinal distributions of birds, mammals, people, forests, and parks in Nepal. *Conservation Biology* 7:420-423.

Hunter, M.L., Jr., G.L. Jacobson, Jr., and T. Webb, III. 1988. Paleoecology and the coarse filter approach to maintaining biological diversity. *Conservation Biology* 2:375-385.

Krohn, W.B. and R.D. Kelly, Jr. 1997. A conservation and public lands database for Maine: Project history and database documentation. Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono. 16 pp.

Krohn, W.B., R.B. Boone, and S.L. Painton. 1999. Quantitative delineation and characterization of hierarchical biophysical regions of Maine. *Northeastern Naturalist* 6:139-164.

Krohn, W.B., R.B. Boone, S.A. Sader, J.A. Hepinstall, S.M. Schaefer, and S.L. Painton. 1999. Maine Gap Analysis – a geographic analysis of biodiversity. Final contract report to USGS Biological Resources Division, Gap Analysis Program, Moscow, Idaho. 120 pp. plus appendices.

Leader-Williams, N., J. Harrison, and M.J.B. Green. 1990. Designing protected areas to conserve natural resources. *Scientific Progress Oxford* 74:189-204.

Maine Atlas and Gazeteer, Fourteenth Edition, Delorme Mapping Company. 1989. Freeport, ME.

Maine Office of GIS (MOGIS). 1997. 1:24,000 Base Layers. Produced by the MOGIS for the Maine GIS Executive Council, 2 CD set (for more metadata information, see http://apollo.ogis.state.me.us).

Margules, C.R., A.O. Nichols, and R.L. Pressey. 1988. Selecting networks of reserves to maximise biological diversity. *Biological Conservation* 43: 663-676.

Margules, C.R., A.O. Nicholls, and M.B. Usher. 1994. Apparent species turnover, probability of extinction and the selection of nature reserves: a case study of the Ingleborough Pavements. *Conservation Biology*, 3:398-409.

Margules, C.R. 1999. Conservation planning at the landscape scale. Issues in Landscape Ecology. International Association for Landscape Ecology, Fifth World Congress, Snowmass Village, CO. 151 pp.

McMahon, J.S. 1990. The biophysical regions of Maine: patterns in the landscape and vegetation. MS. Thesis, University of Maine, Orono. 119 pp.

Noss, R.F. 1983. A regional landscape approach to maintain biodiversity. *BioScience* 33: 700-705.

Noss, R.F. 1987. From plant communities to landscapes in conservation inventories: A look at The Nature Conservancy (USA). *Biological Conservation* 41: 11-37.

Plantinga, A.J., T. Mauldin, and R.J. Alig. 1999. Land use in Maine: determinants of past trends and projections of future changes. Res. Pap. PNW-RP-511. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 20 pp.

Prendergast, J.R., R.M. Quinn, and J.H. Lawton. 1998. The gaps between theory and practice in selecting nature reserves. *Conservation Biology* 13:484-492.

Pressey, R.L. 1992. Nature conservation in rangelands: lessons from research on reserve selection in New South Wales. *Rangeland Journal* 14:214-226.

Pressey, R.L., C.J. Humphries, C.R. Margules, R.I. Vane-Wright, and P.H. Williams. 1993. Beyond Opportunism: key principles for systematic reserve selection. *Trends in Ecology and Evolution* 8:124-128.

Pressey, R.L. 1994. Ad hoc reservations: forward or backward steps in developing representative reserve systems? *Conservation Biology* 8:662-668.

Pressey, R.L. and V.S. Logan. 1994. Level of geographic subdivision and its effects on assessments of reserve coverage: A review of regional studies. *Conservation Biology* 8:1037-1046.

Pressey, R.L. and S.L. Tully. 1994. The cost of *ad hoc* reservation: A case study in western New South Wales. *Australian Journal of Ecology* 19:375-384.

Scott, J.M, F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T.G. Edwards, Jr., J. Ulliman, and G.R. Wright. 1993. Gap Analysis: a geographic approach to protection of biological diversity. *Wildlife Monographs* 123:1-41.

Wallace, J.M. and P.V. Hobbs. 1977. Atmospheric Science. Academic Press, New York, NY. 467 pp.

Wright, R.G., and P.D. Tanimoto. 1998. Using GIS to prioritize land conservation actions: Integrating factors of habitat diversity, land ownership, and development risk. *Natural Areas Journal* 18:38-44.

CHAPTER 3

A REPRESENTATIONAL ANALYSIS OF STATE AND FEDERAL WILDLIFE AREAS IN MAINE

INTRODUCTION

Conservation areas are typically located on an opportunistic or *ad hoc* basis (Pressey and Tully 1994; Hunter and Yonzon 1993), and recent findings show current conservation lands occur most frequently in high elevation and low soil productivity areas (Chapter 1, Scott *et al.* 2000). Low to medium elevation and high soil productivity areas are generally in private ownership leaving ecosystems and species in them largely unprotected (Knight 1999). The low to medium elevation and high soil productivity areas must be included if representative samples of an areas natural variation are to be conserved. Given the growing concern for biodiversity conservation, the question becomes how well are state and federal wildlife management lands serving broader conservation goals by capturing the full representation of natural systems in a state?

Currently, the acquisition of Wildlife Management Areas (WMA's) in Maine, managed by the Maine Department of Inland Fisheries and Wildlife (MDIFW), have no standard process or fund for land acquisition and most purchases occur as a result of opportunistic factors such as land availability at a given time (MDIFW [Unpublished]). Recently, MDIFW has established specific objectives to acquire important wildlife habitats, including habitats essential for the conservation of endangered and threatened species, and lands necessary to achieve objectives in species management plans (MDIFW [Unpublished]). National Wildlife Refuges (NWR's), administered by the U.S. Fish and Wildlife Service (USFWS), originally targeted wetlands and hunted waterfowl habitat, but have expanded more recently to include habitats for federally listed threatened and endangered species and a broad range of habitats for game species (National Research Council 1993). NWR's lack a unified management strategy for designating lands (Gergely 2000). For NWR's or WMA's, land acquisition has not been designed specifically to preserve habitats for all wildlife species, nor natural ecosystems, although there is increasing recognition that state and federal land acquisition systems should aim to represent ecosystems as completely as possible (National Research Council 1993).

According to the National Research Council (1993), "… the Federal land acquisition process does not adequately address the need for protecting natural areas as scientifically credible baselines to measure the effects human use has on resources." Standards for determining what areas are present in the system and how they should be protected needs to be consistent among all federal agencies (National Research Council 1993). Thus, public and private conservation organizations should take into account regional conservation needs as well as social and economic concerns (National Research Council 1993).

The purpose of this analysis is to evaluate the contributions of WMA's and NWR's to the conservation of biodiversity in Maine as indicated by selected abiotic and biotic factors. Specific objectives are to determine the:

(1) Distribution of major geomorphic factors (i.e., aspect, elevation, and slope) on WMA's and NWR's relative to what occurs statewide and by the major biophysical regions;

(2) Distribution of major vegetation types on WMA's and NWR's relative to what occurs statewide and by major biophysical regions;

(3) Number of terrestrial (i.e., non-fish, non-marine) vertebrates present on WMA's and NWR's relative to what occurs statewide and by major biophysical regions; and

(4) Examine the above data on species numbers and vegetation areas amounts by taxonomic classes (i.e., amphibians, birds, mammals, and reptiles) and ecological groups (i.e., forest specialists, forest generalists, water/wetland users, open habitats/barren ground users, and early successional users).

STUDY AREA

My study area is the state of Maine, located approximately 450 km north to south and 320 km east to west and covering more than 83,000 km^2. Maine supports a variety of physical settings from the Appalachian Mountain chain and Mount Katahdin to the rocky coastline, along with vast forestlands and wetland complexes. Elevation in Maine ranges from 0 to 1359 m above mean sea level (msl), with the southern areas generally below 300 m. There is a 50-100 km-wide band stretching east-west within the state, where many southern species reach their northern limit, and a number of northern woody plant species reach their southern limit (Boone and Krohn 2000a,b). A similar band of range limits of plant species runs north-south (McMahon 1990). These bands of increased species richness increase the diversity and complexity of ecosystems, which in-turn is associated with more vertebrate species (Boone and Krohn 2000a). The highest number of woody plants and breeding terrestrial vertebrates occur in southern Maine (Boone and Krohn 2000a, McMahon 1990).

METHODS

State and Federal Wildlife Areas

The Conservation and Public Lands Database (CAPLD) (scale = 1:100,000) incorporates, in digital format, the federal, state, municipal, and private conservation agencies and organizations in Maine as of 1997 (Krohn and Kelly 1997). Federally owned National Wildlife Refuge (NWR) and state managed Wildlife Management Areas (WMA) boundaries were extracted from CAPLD into a separate GIS layer (Figure 3.1). Boundaries of NWR's in Maine were updated from the USFWS national dataset (USFWS 2000). The following conservation easements and other non-fee title areas, managed by the Maine Department of Inland Fisheries and Wildlife (MDIFW), were included in the analysis: Spednik Lake, Thurston Meadow, Pleasant Acres, Race Point, Tunk Lake, Tomah Stream Flowage, Roach River, Egypt Bay, Englishman's River, Hurd Pond, Tide Mill Farm, South Lubec Sand Bar, Tolla Wolla, Lyons Property, George Buckman, and Bachman (See Appendix 2 for spatial location).

Variable Analysis

Three abiotic and two biotic variables were analyzed, specifically elevation, slope, aspect, terrestrial vertebrate richness, and vegetation classes. The representation of each variable on NWR's and WMA's was analyzed in a GIS using ArcGrid, a module of ARC/INFO Version 7.2 (Windows NT) (Environmental Systems Research Institute, Redlands, California, USA; use of trade names does not imply endorsement), with a cell

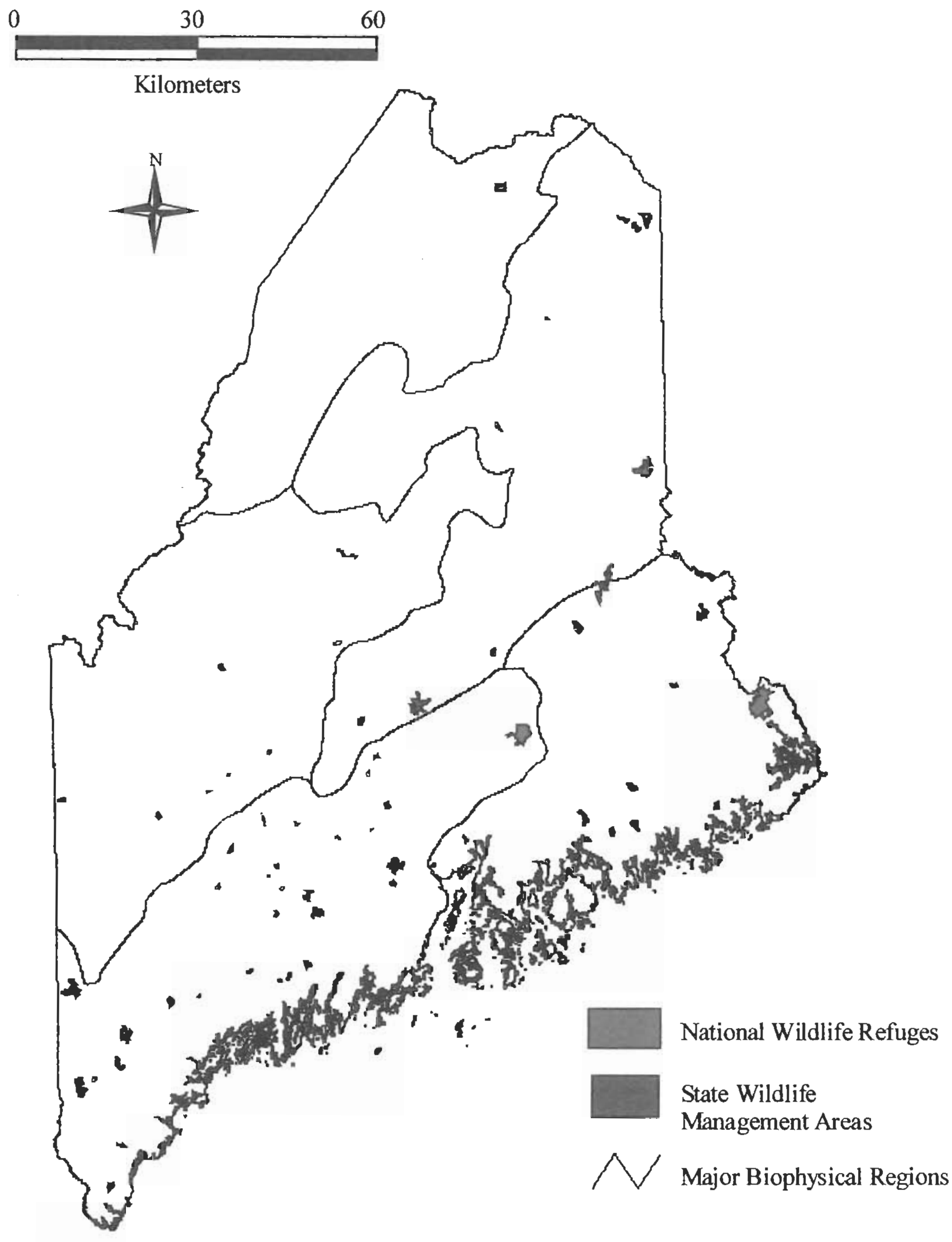


Figure 3.1. Location of major State WMA's and all Federal NWR's analyzed in Maine. Locations of biophysical regions modified from Krohn *et al.* (1999).

size of 94.6 x 94.6 m. Due to the size of the databases, the variables were subdivided into evenly distributed classes. For example, elevation was grouped by 0–200 m, 201–400 m, etc. These variable classes were overlaid with NWR's and WMA's and were compared to areas outside WMA and NWR boundaries. Then, a table was created for each variable, which summarized the representation in state and federal wildlife areas.

Representational analyses are most meaningful when limited to a relatively homogeneous areas (Leader-Williams *et al.* 1990). Krohn *et al.* (1999) quantitatively delineated the state into 13 biophysical regions, and I modified these 13 regions into five major regions of roughly equal size (Figure 3.1). Each variable's representation in NWR's and WMA's was compared to the representation in areas outside NWR's and WMA's. These results were summarized for each major biophysical region in Maine.

Abiotic Variables

A range of physical factors in their environment, including climate (Cox and Moore 1993) affects plants and animals. "Any climatic or topographic factor, or combination of factors, may provide a barrier to the distribution of an organism," according to Cox and Moore (1993). Mountainous regions hold plant communities that are spatially compacted relative to flat regions resulting in a positive relationship between mountainous areas and some species distributions (Boone 1996). A digital elevation model (DEM) at 94.6 m resolution covering Maine was published by the U.S. Geological Survey (USGS), acquired from the Maine State Office of GIS (Augusta, ME), and assembled into a seamless GIS coverage for Maine by Boone (1996).

Biotic Variables

Vegetation patterns on a landscape scale influence abiotic and biotic processes (Turner 1990, Chokkalingam 1998). Vegetation classes investigated for this analysis were modified from the vegetation and land cover map of Maine developed for the Maine Gap Analysis project (Hepinstall *et al.* 1999). The vegetation and land cover map of Maine was developed using Landsat-Thematic Mapper satellite imagery, along with ancillary GIS data (e.g., USFWS National Wetlands Inventory [NWI] maps). Image classification delineated 37 different classes of vegetation and land cover and attempted to capture conditions as of 1993 (Hepinstall *et al.* 1999). For each WMA and NWR, the occurrence of current, dominant cover types as shown by the land cover and vegetation map developed for the Maine Gap Analysis project (Hepinstall *et al.* 1999) was analyzed.

Terrestrial vertebrate richness grids were created for the Maine Gap Analysis Project based on predictions of occurrence from the wildlife habitat relationship models (Krohn *et al.* 1999). There are 270 native terrestrial vertebrate species considered to be regular breeders in Maine, consisting of 17 amphibians, 16 reptiles, 183 birds, and 54 mammals (Krohn *et al.* 1999). The species richness grid has a value representing the total number of species predicted to occur on that cell for every cell in the state. The accuracy assessment of the terrestrial vertebrate predictions showed low ommision rates (when a species is recorded but not predicted) and high commission rates (when a species is predicted but not recorded). However, much of this commission error was due to incomplete field surveys versus real errors (Schaefer and Krohn 2002). I used these grids to determine the mean number of terrestrial vertebrate species (i.e., amphibians, birds, mammals, and reptiles) predicted to occur on, and off, of state and federal wildlife areas.

For example, to determine the mean number of species predicted to occur on WMA's in the St. Johns Upland Region, I multiplied each species richness value by the number of cells having that species richness value, summed them, and divided that number by the total number of cells in WMA's for that region.

In addition, each species was placed in one, and only one, of five groups associated with the habitat type they most likely use for breeding. The groupings, based on Gawler *et al.* (1996), were as follows: (1) Barren and Urban Specialists, (2) Early Successional, (3) Wetlands and Waterbodies, (4) Forest Generalists, and (5) Forest Specialists (i.e., using predominantly coniferous *or* deciduous). By tallying the number of cells with a predicted occurrence of each ecological group, I then calculated the percent of the area on WMA's and NWR's and off for each major biophysical regions.

RESULTS

In Maine, 75 WMA's and other areas owned or managed by the MDIFW comprised 334.1 km^2, or 0.4 % of the state whereas the 7 National Wildlife Refuges covered 200.8 km^2, or 0.2% of Maine (Table 3.1). WMA's were distributed in all 5 of Maine's major biophysical regions whereas NWR's are absent in the St. John Uplands Region in northwestern Maine, but present in all other regions (Figure 3.1). WMA's occupy the most area in the Coastal Plain and Foothills Region and least area in the Western and Interior Mountains and St. John Upland regions (Table 3.1). In southern Maine (i.e., Eastern Lowlands and Foothills and the Coastal Plain and Foothills Region), NWR's account for most of the area (Table 3.1). NWR's occupy the least amount of area in the Western and Interior Mountains Region (0.1%) (Table 3.1).

Table 3.1. The percent (%) and area (km^2) of the region in State and Federal wildlife areas by major biophysical regions of Maine.

Biophysical Regions [a]	**State Wildlife Management Areas**		**National Wildlife Refuges**		**Percent of each region in State and Federal wildlife areas**
	Percent of area in region	Area (km^2)	Percent of area in region	Area (km^2)	
St. John Uplands	0.1	17	0	0	0.1
Foothills & St. John	0.4	75	0.1	21	0.5
Western & Interior Mountains	0.1	12.4	0	3.7	0.1
Eastern Lowlands & Foothills	0.6	79	0.7	103.5	1.4
New England Coastal Plain	0.8	150.4	0.4	72.6	1.2
Statewide Totals	0.4	333.8	0.2	200.8	0.6

[a] - Modified from Krohn *et al.* (1999); see Figure 3.1.

Table 3.2. The percent (%) and area (km^2) of the region in elevation (m above msl) ranges on state and Federal wildlife areas and off by major biophysical regions of Maine.

Biophysical Regions[a]	State Wildlife Management Areas (WMA's) Elevation % (Area (km^2))			Federal National Wildlife Refuges (NWR's) Elevation % (Area (km^2))			Outside WMA's and NWR's Elevation % (Area (km^2))		
	0 - 200m	201 - 400m	401 - 600m	0 - 200m	201 - 400m	401 - 600m	0 - 200m	201 - 400m	401 - 1359m
St. John Uplands	0 (0)	74.5 (12.7)	25.5 (4.3)	N/A	N/A	N/A	1.8 (224.2)	65.9 (8,157.5)	32.3 (4,000.5)
Interior Foothills & St. John Valley	96 (72)	4 (3)	0 (0)	32.4 (6.8)	67.6 (14.2)	0 (0)	50.1 (9,885.4)	49.1 (9,693.8)	0.8 (158.9)
Western & Interior Mountains	13.6 (1.7)	85.2 (10.6)	1 (0.1)	0 (0)	40.4 (1.5)	59.6 (2.2)	10.5 (19,93.7)	43.2 (8,179.6)	46.2 (8,753.1)
Eastern Lowlands & Foothills	100 (79)	0 (0)	0 (0)	100 (103.5)	0 (0)	0 (0)	97.1 (12,700)	2.9 (383.6)	0 (0)
Coastal Plain & Foothills	90 (135.4)	10 (15)	0 (0)	100 (72.6)	0 (0)	0 (0)	95.5 (17,300.4)	4.5 (819.4)	.02 (3.6)

[a]- Modified from Krohn *et al.* (1999); see Figure 3.1.

Statewide, WMA's have about 288 km^2 between 0 and 200 m elevations, while 41 km^2 are between 201 and 400 m and 4.4 km^2 are between 401 and 600 m (Table 3.2). NWR's have 182.9 km^2 in elevations between 0 and 200, while 16 km^2 are between 201 and 400 m and 2.2 km^2 between 401 and 600 m (Table 3.2). One exception is in the Western and Interior Mountains Region where more of the high elevation areas are occupied by NWR's and WMA's (Table 3.2).

Compared to areas outside state and federal wildlife areas, WMA's well-represent the elevation ranges for the St. Johns Uplands, the Eastern Lowland and Foothills, and the Coastal Plain and Foothills regions (Table 3.2). In the Interior Foothills and St. John Valley Region, WMA's have 96% between 0 and 200 m and 4% between 201 and 400 m, while outside WMA's and NWR's have 50% and 49%, respectively. In the Western and Interior Foothills Region, WMA's have 85% between 201 and 400 m and 1% between 401 and 600 m, while outside WMA's and NWR's have 43.2 and 46.2%, respectively. Except for their absence from the St. John's Upland Region in northern Maine, NWR's are fairly representative of the elevation ranges outside WMA's and NWR's.

Most WMA's and NWR's have relatively more low degrees of slope than high degrees (Table 3.3). The WMA's have 272.9 km^2 and NWR's have 193.1 km^2 between 0 and 3 degrees of slope (Table 3.3). WMA's and NWR's represent very few areas over 7 degrees of slope (Table 3.3). For aspect classes, WMA's have a higher percent (61%) between 271 and 360 degrees in the Western and Interior Mountains Region compared to areas outside WMA's and NWR's, but were fairly representative of aspect classes in the other biophysical regions (Table 3.4). NWR's have the highest percent between 271 and 360 degrees in the Interior Foothills and St. John Valley and Eastern Lowland and

Table 3.3. The percent (%) and area (km^2) of slope (degrees) on State and Federal wildlife areas and off by major biophysical regions of Maine.

Biophysical Regions[a]	Management Areas (WMA's) Slope			Federal National Wildlife Refuges (NWR's) Slope			Outside WMA's and NWR's Slope		
	0 - 3	4 - 6	7 - 15	0 - 3	4 - 6	7 - 15	0 - 3	4 - 6	7 - 15
	Percent (Area (km^2))			Percent (Area (km^2))			Percent (Area (km^2))		
St. John Uplands	52 (8.9)	21.6 (3.7)	27 (4.6)	N/A	N/A	N/A	68.6 (8,495.4)	21.8 (2,692.4)	9.6 (1,194.5)
Interior Foothills & St. John Valley	89.9 (67.4)	5.7 (4.3)	4.39 (3.3)	100 (21.1)	0 (0)	0 (0)	89.2 (17,611.9)	8.1 (1,602.1)	2.7 (524.1)
Western & Interior Mountains	72.9 (9.1)	24.8 (3.1)	2.4 (0.3)	51.5 (1.9)	12.2 (.5)	36 (1.33)	51.1 (9,675.5)	20.3 (3,851.2)	28.5 (5,399.5)
Eastern Lowlands & Foothills	94.6 (74.8)	2.9 (2.3)	2.4 (1.9)	94.3 (97.7)	5.6 (5.8)	0 (0)	86.6 (11,334.2)	8.8 (1,153.4)	0.1 (596.1)
Coastal Plain & Foothills	75 (112.8)	15.5 (23.3)	9.4 (14.2)	99.5 (72.3)	0.5 (.4)	0 (0)	86.3 (15,649)	9.9 (1,785.8)	3.8 (688.7)

[a] - Modified from Krohn *et al.* (1999); see Figure 3.1.

Table 3.4. The percent and area (km^2) of aspect (degrees) on State and Federal wildlife areas and off by major biophysical regions of Maine.

Biophysical Regions[a]	State Wildlife Management Areas (WMA's)				Federal National Wildlife Refuges (NWR's)				Outside WMA's and NWR's			
	Aspect				Aspect				Aspect			
	0 - 90	91 - 180	181 - 270	271 - 360	0 - 90	91 - 180	181 - 270	271 - 360	0 - 90	91 - 180	181 - 270	271 - 360
	Percent (Area (km^2))				Percent (Area (km^2))				Percent (Area (km^2))			
St. John Uplands	32.7 (5.6)	7 (1.2)	27.5 (4.7)	32.7 (5.6)	N/A	N/A	N/A	N/A	24.8 (3065.3)	22.6 (2803.8)	23.6 (2928.4)	29 (3584.8)
Interior Foothills & St. John Valley	15.3 (11.4)	24.3 (18.3)	10.9 (8.2)	49.6 (37.2)	8.4 (1.8)	12.8 (2.7)	26.6 (5.6)	52.2 (11)	20.2 (3990.3)	22.9 (4527)	20.3 (4007.2)	36.5 (7213.6)
Western & Interior Mountains	2.4 (0.3)	25.7 (3.2)	12 (1.5)	60.9 (7.6)	39 (1.4)	0 (0)	11.9 (0.4)	49.6 (1.8)	22.4 (4243.3)	25.5 (4843.3)	23.4 (4436.4)	28.6 (5404.2)
Eastern Lowlands & Foothills	19 (15)	14.3 (11.3)	17.5 (13.8)	49.2 (38.9)	12.9 (13.4)	8.1 (8.4)	9.9 (10.2)	69.6 (72)	21.9 (2863.9)	19 (2483.3)	21.8 (2,850.8)	37.3 (4885.9)
Coastal Plain & Foothills	24.9 (37.4)	22.3 (33.5)	17.1 (25.7)	35.8 (53.8)	5.9 (4.3)	35.3 (25.6)	30.9 (22.4)	28 (20.3)	20.1 (3641.8)	24.8 (4502.1)	20 (3616)	35.1 (6363.5)

[a]- Modified from Krohn *et al.* (1999); see Figure 3.1.

Foothills regions with 52% and 70%, respectively, compared to 37% for areas outside NWR's and WMA's for both regions (Table 3.4).

Of the 334 km^2 of WMA's in Maine, 204 km^2 are upland cover types, 105 km^2 are wetland cover types, and 20 km^2 are open water (Table 3.5). In WMA's, the wetland cover types consistently have approximately twice the percent in conservation than non-conservation for all the major biophysical regions except the St. John Uplands region (Table 3.5). The same pattern occurs for wetland cover types in NWR's, with the exception of the Eastern Foothills and Lowlands region (Table 3.5).

For WMA's, the unforested wetland cover types are over-represented across the all the major biophysical regions and the upland cover types are under-represented with the exception of the hardwood forests (Table 3.6). For NWR's, the unforested wetlands are also over-represented across all the regions, except for the St. John Uplands and the forested wetlands in the Interior Foothills and Lowlands, Western and Interior Mountains, and the Coastal Plain regions (Table 3.6). The upland cover types have smaller percentages in conservation versus non-conservation for all the regions except the mixed forest in the Interior Foothills and softwood forests in the Eastern Lowlands and Foothills and the Coastal Plain and Foothills regions (i.e., southern Maine). The absence of NWR's from the St. John Upland Region accounts for some of the under-representation of uplands; however, the other regions were under-represented in most upland cover types as well.

Table 3.5. The area (km²) and percent (%) of the region in major cover types on State and Federal wildlife areas by major biophysical regions of Maine.

Biophysical Regions [a]	State Wildlife Management Areas (WMAs)			National Wildlife Refuges (NWRs)			Off WMA's and NWR's		
	Cover types			Cover types			Cover types		
	Water	Wetlands	Uplands	Water	Wetlands	Uplands	Water	Wetlands	Uplands
	% (km^2)	% (km^2)	% (km^2)	% (km^2)	% (km^2)	% (km^2)	% (km^2)	% (km^2)	% (km^2)
St. John Uplands	2.3 (0.4)	5.8 (1.0)	91.8 (15.7)	0 (0)	0 (0)	0 (0)	2.5 (303.9)	7.8 (961.6)	89.7 (11065.7)
Interior Foothills & St. John Valley	2.9 (2.1)	38.3 (27.7)	58.8 (42.5)	3.4 (0.6)	29 (5.2)	67.6 (12.1)	6.1 (1099.5)	15.4 (2766.9)	78.5 (14130.5)
Western & Interior Mountains	9.8 (1.2)	29.5 (3.6)	60.7 (7.4)	0 (0)	82.1 (3.2)	17.9 (0.7)	6.5 (1198.4)	6.3 (1156.6)	87.2 (16086.9)
Eastern Lowlands & Foothills	14.8 (12.1)	39.4 (32.5)	45.7 (37.6)	4.6 (4.7)	18.5 (19.0)	76.9 (78.8)	8.0 (1002.1)	15.6 (1947.4)	76.4 (9540.3)
Coastal Plain & Foothills	3.1 (4.5)	27.7 (40.2)	69.2 (100.4)	29 (2.1)	36.8 (43.3)	36.8 (26.4)	7.1 (1038.2)	15.2 (2224.6)	77.8 (11404.8)

[a] - Modified from Krohn *et al.* (1999); see Figure 3.1.

Table 3.6. The percent (%) of major cover types on State and Federal wildlife areas and off by major biophysical regions of Maine.

Biophysical Regions[a]	State Wildlife Management Areas (WMA's)						National Wildlife Refuges (NWR's)						Outside WMA's and NWR's					
	Cover Types						Cover Types						Cover Types					
	Wetlands[b]		Uplands[c]				Wetlands[b]		Uplands[c]				Wetlands[a]		Uplands[b]			
	FR %	UF %	ES %	HF %	MF %	SF %	FR %	UF %	ES %	HF %	MF %	SF %	FR %	UF %	ES %	HF %	MF %	SF %
St. John Uplands	4.6	1.1	17.1	46.3	27.8	0.6	0	0	0	0	0	0	5.1	2.6	24.8	17.9	36.8	9.4
Interior Foothills & St. John Valley	25.1	11.8	2.2	12.6	35.9	6.1	15.9	8.8	2.4	0.2	53.6	1.4	9.4	4.6	12.6	12	36.3	10.6
Western & Interior Mountains	2	26.8	7	21	21.1	10.6	69.2	13	6	0.9	8.3	1.9	3.4	2.7	16.2	25.8	34.7	8.1
Eastern Lowlands & Foothills	9.9	28.4	6.5	2.9	27	7.7	4.4	12.6	10.3	4.3	37	19	6.8	7	12.9	6.1	38.2	10.3
Coastal Plain & Foothills	10.7	15.6	8.4	18.6	32	6.6	16.9	40.1	3.6	0.7	23.9	6.5	6.6	5.4	7	12.6	36.3	6.1

[a] - modified from Krohn *et al.* (1999); see Figure 3.1.

[b] - FR = forested, UF = unforested

[c] - ES = early successional, HF = hardwood forests, MF = mixed forests, and SF = softwood forests

Of the 270 terrestrial vertebrates across Maine, the average number predicted to occur on WMA's was 219 and 223 on NWR's (Table 3.7). WMA's showed a good representation of each taxanomic group of vertebrates on all 5 biophysical regions in Maine, except for reptiles in the St. John Uplands Region (Table 3.7). In the St. John Uplands Region, the absence of NWR's resulted in the under-representation of all terrestrial vertebrates compared to areas outside NWR's and WMA's. Reptiles had a smaller mean number represented on NWR's than off, while bird mean numbers were fairly even and often larger than mean numbers off state and federal wildlife areas. The mean number of mammals predicted to occur on NWR's was slightly smaller than the mean number for areas outside NWR"s and WMA's for all 5 biophysical regions (Table 3.7). Amphibian mean numbers were smaller than numbers off state and federal wildlife areas in all 5 regions except the Coastal Plain and Foothills Region (Table 3.7).

All five ecological groups of terrestrial vertebrates (i.e., barren and urban species, early successional species, wetland and open water species, forest generalists, and forest specialists) in Maine were well-represented on the five major biophysical regions (Table 3.8). For all the regions, except the St. John's Upland Region in the northwestern part of the state, there was a higher average of Wetland and Open Water Species on than off WMA's (Table 3.8). The NWR's showed a good representation of the five ecological groups of vertebrates in all five regions except the St. John's Upland Region where NWR's are not present (Table 3.8). The wetland and open water species were relatively more abundant within NWR boundaries than outside these areas in all regions except the St. John's Upland Region (Table 3.8).

Table 3.7. The mean number of breeding terrestrial vertebrates predicted to occur on and off State and Federal wild areas by taxonomic classes and major biophysical regions of Maine.

Biophysical Regions[a]	State Wildlife Management Areas								National Wildlife Refuges							
	Amphibians		Reptiles		Birds		Mammals		Amphibians		Reptiles		Birds		Mammals	
	On mean no.	Off mean no.	On mean no.	Off mean no.	On mean no.	Off mean no.	On mean no.	Off mean no.	On mean no.	Off mean no.	On mean no.	Off mean no.	On mean no.	Off mean no.	On mean no.	Off mean no.
St. John Uplands	13	14	2	4	138	140	44	46	0	14	0	4	0	138	0	44
Interior Foothills & St. John Valley	16	15	7	6	146	144	45	46	12	15	4	6	143	144	43	46
Western & Interior Mountains	15	16	6	8	146	147	47	47	15	16	5	8	151	147	49	47
Eastern Lowlands & Foothills	15	16	8	9	156	155	44	45	15	16	7	9	161	155	43	45
Coastal Plain & Foothills	16	16	11	11	147	149	47	47	16	16	10	11	153	149	45	47
Statewide Totals	15	15	8	8	149	147	46	46	15	15	8	8	152	147	46	46

[a] - Modified from Krohn et al. (1999); see Figure 3.1.

Table 3.8. The percent of the area in WMA's, NWR's, and outside WMA's and NWR's with breeding terrestrial vertebrates predicted to occur for each ecological group[a] and major biophysical region[b] of Maine.

Biophysical Regions	**State Wildlife Management Areas (WMA's)**					**National Wildlife Refuges (NWR's)**					**Outside WMA's and NWR's**				
	BU	ES	WW	FG	FS	BU	ES	WW	FG	FS	BU	ES	WW	FG	FS
St. John Uplands	2.1	9.9	10.7	64.0	17.0	0.0	0.0	0.0	0.0	0.0	2.4	11.4	10.9	62.4	20.1
Interior Foothills & St. John Valley	2.8	11.4	24.0	64.9	20.6	3.1	10.4	20.2	58.4	21.6	2.8	10.8	15.0	60.0	19.4
Western & Interior Mountains	2.9	12.6	21.5	59.7	16.8	2.3	15.0	32.2	64.7	23.7	2.6	11.2	11.3	62.6	18.4
Eastern Lowlands & Foothills	3.5	12.7	26.2	53.3	17.4	3.0	12.1	18.9	59.4	21.5	2.9	11.5	16.0	56.0	18.7
Coastal Plain & Foothills	4.1	12.3	20.2	60.2	14.8	3.7	13.0	29.4	52.9	14.5	4.6	13.4	16.5	57.9	14.2

[a] - BU = Barren and Urban Species, ES = Early Successional, WW = Wetland and open water species, FG = Forest generalists and FS = Forest Specialists (groups based on Gawler *et al.* 1996).

[b] - Modified from Krohn *et al.* (1999); see Figure 3.1.

DISCUSSION

Results of representational studies of wildlife areas conducted in Washington (Cassidy *et al.* 1997) and Idaho (Karl *et al.* [In Preparation]) differ from this study. In Washington, Cassidy *et al.* (1997) showed wetlands in low elevation areas in east and west forests, upland woodlands and prairie habitat in low elevation west-side zones, and upland deep-soil habitat are high priorities for conserving. In Idaho, Karl *et al.* [In Preparation] showed WMA's also tend to be in low elevation areas due to critical game species winter ranges. They did not adequately represent the shrub-steppe cover types, an ecosystem considered endangered. Overall, state WMA's in Idaho were representative of the state's ecological diversity (Karl *et al.* [In Preparation]).

The intent of this analysis was to show how WMA's and NWR's were representing some natural diversity elements across the five biophysical regions of Maine. A biodiversity management perspective was used in this analysis, and it should be understood that many other factors, beyond the scope of this analysis, must be considered by wildlife managers (i.e., recreational value and game species management). On a statewide basis, conservation lands are under-represented in southern and eastern Maine (Chapter 1). However, when only WMA's and NWR's are analyzed, the areas are well-represented across Maine except in the northern regions. WMA's and NWR's representation was compared to areas outside WMA's and NWR's boundaries. Therefore, a small percent (~2%) of these outside areas are already protected by other conservation lands not included in this analysis.

WMA's are distributed throughout Maine, but are most abundant in southern Maine. WMA's over-represent wetlands and hardwood forests and under-represent early successional, mixed, and softwood forests when compared with areas outside state and federal wildlife areas. WMA's adequately represent potential habitats for birds, mammals, and amphibians across the state, and under-represent reptiles in the St. John Upland and Western and Interior Mountain regions. WMA's occupy mainly low elevation and relatively flat areas.

NWR's are also more prevalent in southern than northern Maine and occupy areas with low elevation and low degrees of slope. There are more wetland cover types and fewer upland cover types on NWR's when compared to areas outside state and federal wildlife areas. NWR's have smaller mean numbers for reptiles across the state, but are fairly representative of mammals, birds, and amphibians mean numbers. NWR's are absent from the St. John Upland Region in northwestern Maine leading to an under-representation of all variables studied in this analysis compared to areas outside NWR's and WMA's.

In representational analyses, different variables can be selected based on the purpose of your analysis and also what variables are available in a GIS format. For this analysis, our purpose was to assess how well WMA's and NWR's were representing the natural diversity in the state, given emerging, broader management objectives (i.e., from game to wildlife habitats). The abiotic variables are considered better measures of the natural diversity because they are more stable measures over a long period of time, compared to biotic variables, which are often short-term inhabitants of the landscape (e.g., Hunter *et al.* 1988). Also, abiotic variables are often more readily available in GIS datasets. The vertebrate data used in this analysis are a crude measure of species richness and should be interpreted with caution.

To more adequately represent the ecological diversity in the state, both WMA's and NWR's should focus acquisition on a representative set of environments in northwestern Maine. Throughout the rest of the state, both types of wildlife areas need to concentrate on the conservation of mid- to high-elevation areas. Conserving mid-elevation forestlands, however, will be difficult as these are the same lands on concentrated ownership by commercial forestry companies (Krohn *et al.* 1999). Thus, as an alternative to government ownership, more emphasis and technical assistance could be provided to improve the management systems being applied to these private lands. To some degree, this is happening in Maine and should be continued and encouraged.

LITERATURE CITED

Boone, R.B. 1996. An assessment of terrestrial vertebrate diversity in Maine. Ph.D. Dissertation, University of Maine, Orono, ME. 222 pp.

Boone, R.B. and W.B. Krohn. 2000a. Partitioning sources of variation in vertebrate species richness. *Journal of Biogeography* 27:457-470.

Boone, R.B. and W.B. Krohn. 2000b. Relationship between avian range limits and plant transition zones in Maine. *Journal of Biogeography* 27:471-482.

Cassidy, K.M., M.R. Smith, C.E. Grue, and R.E. Johnson. 1997. The role of Washington State's National Wildlife Refuges in conserving the State's biodiversity. Washington Cooperative Fish and Wildlife Research Unit, University of Washington, Seattle. 86 pp.

Cox, B. and P. Moore. 1993. <u>Biogeography: An ecological and evolutionary approach</u> 5E. Blackwell Science, Inc. Cambridge, MA. 298 pp.

Chokkalingam, U. 1998. Spatial and temporal patterns and dynamics in old growth northern hardwood and mixed forests of northern Maine. Ph.D. Dissertation, University of Maine, Orono, ME. 95 pp.

Gawler, S.C., J.J. Albright, P.D. Vickery, F.C. and Smith. 1996. Biological diversity in Maine: An assessment of status and trends in the terrestrial and freshwater landscape. Maine Natural Areas Program, Department of Conservation, Augusta, ME. 77 pp.

Gergely, K., J.M. Scott, and D. Goble. 2000. A new direction for the U.S. National Wildlife Refuges: the National Wildlife Refuge System Improvement Act of 1997. *Natural Areas Journal*, 20:107-118.

Habitat Acquisition Plan, Wildlife Division. In Preparation. Maine Department of Inland Fisheries and Wildlife. Unpublished Internal Report, Bangor, Maine.

Hepinstall, J.A., S.A. Sader, W.B. Krohn, R.B. Boone, and R.I. Bartlett. 1999. Development and testing of a habitat and land cover map of Maine. Maine Agriculture and Forest Experiment Station, Technical Bulletin 173, University of Maine, Orono. 104 pp.

Hunter, M.L., Jr. G.L. Jacobson, Jr., and T. Webb, III. 1988. Paleoecology and the coarse filter approach to maintaining biological diversity. *Conservation Biology* 2:375-385.

Hunter, M.L., Jr., and P. Yonzon. 1993. Altitudinal distributions of birds, mammals, people, forests, and parks in Nepal. *Conservation Biology* 7: 420-423.

Karl, J.W., J.M. Scott, and E. Strand. 1999. An assessment of Idaho's wildlife management areas for the protection of wildlife. Idaho Fish and Wildlife Cooperative Research Unit, University of Idaho, Moscow, Idaho. Unpaged.

Knight, R.L. 1999. Private lands: The neglected geography. *Conservation Biology* 13:223-224.

Krohn, W.B. 1996. Predicted vertebrate distributions from gap analysis: considerations in the designs of statewide accuracy assessments. Pages 147 – 162 in Scott, J.M., Tear, T.H., and F.W. Davis (editors). Gap Analysis: a Landscape Approach to Bio-diversity planning. American Society for Photogrammetry and Remote Sensing, Bethesda, MD. 320 pp.

Krohn, W.B. and R.D. Kelly, Jr. 1997. A conservation and public lands database for Maine: Project history and database documentation. Unpublished manuscript. Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono, ME. 16 pp.

Krohn, W.B., R.B. Boone, and S.L. Painton. 1999. Quantitative delineation and characterization of hierarchical biophysical regions of Maine. *Northeastern Naturalist* 6:139-164.

Krohn, W.B., R.B. Boone, S.A. Sader, J.A. Hepinstall, S.M Schaefer, and S.L. Painton. 1998. Maine Gap Analysis – a geographic analysis of biodiversity. Final contract report to USGS Biological Resources Division, Gap Analysis Program, Moscow, Idaho. 120 pp. plus appendices.

Leader-Williams, N., J. Harrison, and M.J.B. Green. 1990. Designing protected areas to conserve natural resources. *Scientific Progress Oxford* 74:189-204.

Leopold, A. 1933. Game Management. Charles Scribner's Sons. New York, New York. 481 pp.

National Research Council. 1993. Setting Priorities for Land Conservation. Committee Scientific and Technical Criteria for Federal Acquisition of Lands for Conservation. National Academy of Sciences, Washington, D.C. 262 pp.

Pressey, R.L., and S.L. Tully. 1994. The cost of *ad hoc* reservation: A case study in western New South Wales. *Australian Journal of Ecology* 19:375-384.

Schaefer, S.M. and W.B. Krohn. 2002. Testing predicted vertebrate occurrences from habitat associations: improving the interpretation of commission error rates. Pages 419-427. In Scott, J. M., P. J. Heglund, M. Morrison, M. Raphael, J. Haufler, B. Wall (editors). Predicting Species Occurrences: Issues of Scale and Accuracy. Island Press. Covello, CA. 868 pp.

Scott, J.M, F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T.G. Edwards, Jr., J. Ulliman, and G.R. Wright. 1993. Gap Analysis: a geographic approach to protection of biological diversity. *Wildlife Monographs* No. 123, 41 pp.

Scott, J.M., F.W. Davis, R.G. McGhie, R.G. Wright, C. Groves, and J. Ester. 2001. Nature Reserves: Do they capture the full range of America's Biological Diversity? *Ecological Applications.*

Turner, M.G. 1990. Spatial and temporal analysis of landscape patterns. *Landscape Ecology* 4:21-30.

United States Fish and Wildlife Service web-site. *ftp://164.159.102.219/pub/refuges/metadata/metadata.html#Maine* (2000).

BIBLIOGRAPHY

Ando, A., Camm, J., Polasky, S., and A. Solow. 1998. Species distributions, land values, and efficient conservation. *Science* 279:2126-2128.

Baskerville, G.L., and P. Emin. 1969. Rapid estimation of heat accumulation from maximum and minimum temperatures. *Ecology* 50:514-517.

Bedward, M., R.L. Pressey, and D.A. Keith. 1992. A new approach for selecting fully representative reserve networks: addressing efficiency, reserve design, and land suitability with an iterative analysis. *Biological Conservation* 62:115-125.

Belbin, L. 1993. Environmental representativeness: Regional partitioning and reserve selection. *Biological Conservation* 66:223-230.

Boone, R.B. 1996. An assessment of terrestrial vertebrate diversity in Maine. Ph.D. Dissertation, University of Maine, Orono, ME. 222 pp.

Boone, R.B. 1997. Modeling the climate of Maine for use in broad-scale ecological analyses. *Northeastern Naturalist* 4:213-230.

Boone, R.B. and W.B. Krohn. 1998a. Maine gap analysis vertebrate data – Part I: distribution, habitat relations, and status of amphibians, reptiles, and mammals in Maine. Part of final contract report to USGS Biological Resources Division, Gap Analysis Program, Moscow, Idaho. 175 pp. plus appendices.

Boone, R.B. and W.B. Krohn. 1998b. Maine gap analysis vertebrate data – Part II: distribution, habitat relations, and status of breeding birds in Maine. Part of final contract report to USGS Biological Resources Division, Gap Analysis Program, Moscow, Idaho. 367 pp. plus appendices.

Boone, R.B. and W.B. Krohn. 2000a. Partitioning sources of variation in vertebrate species richness. *Journal of Biogeography* 27:457-470.

Boone, R.B. and W.B. Krohn. 2000b. Relationship between avian range limits and plant transition zones in Maine. *Journal of Biogeography* 27:471-482.

Brundtland, G.H.(chairperson). 1987. Our Common Future: World commission on environment and development. Oxford University Press, New York, NY, 400 pp.

Burnett, M.R., P.V. August, J.H. Brown, Jr., and K.T. Killingbeck. 1998a. The influence geomorphological heterogeneity on biodiversity, I. A patch-scale perspective. *Conservation Biology* 12:363-370.

Burnett, M.R., P.V. August, J.H. Brown, Jr., and K.T. Killingbeck. 1998b. The influence geomorphological heterogeneity on biodiversity, II. A landscape-scale perspective. *Conservation Biology* 12:371-379.

Caicco, S.L., J.M. Scott, B. Butterfield, and B. Csuti. 1995. A Gap Analysis of the management status of the vegetation of Idaho (U.S.A.). *Conservation Biology* 9:498-511.

Cassidy, K.M., M.R. Smith, C.E. Grue, and R.E. Johnson. 1997. The role of Washington State's National Wildlife Refuges in conserving the State's biodiversity. Washington Cooperative Fish and Wildlife Research Unit, University of Washington, Seattle. 86 pp.

Chokkalingam, U. 1998. Spatial and temporal patterns and dynamics in old growth northern hardwood and mixed forests of northern Maine. Ph.D. Dissertation, University of Maine, Orono. 95 pp.

Cox, B. and P. Moore. 1993. Biogeography: An ecological and evolutionary approach 5E. Blackwell Science, Inc. Cambridge, MA. 298 pp.

Crumpacker, D.W., S.W. Hodge, D.F. Friedley, and W.P. Gregg, Jr. 1988. A preliminary assessment of the status of major terrestrial and wetland ecosystems in the United States. *Conservation Biology* 2:103-115.

Currie, D.J. 1991. Energy and large-scale patterns of animal- and plant- species richness. *American Naturalist* 137:27-49.

Dasmann, R.F. 1972. Towards a system for classifying natural regions of the world and their representation by national parks and reserves. *Biological Conservation* 4:247-255.

Davis, F.W., D.M. Stoms, A.D. Hollander, K.A. Thomas, P.A. Stine, D. Odion, M.I. Borchert, J.H. Thorne, M.V. Gray, R.E. Walker, K. Warner, and J. Graae. 1998. The California Gap Analysis--Final Report. University of California, Santa Barbara, CA. [http://www.biogeog.ucsb.edu/projects/gap/gap_rep.html]

Davis, F.W., J.M. Scott, D.M. Stoms, J.E. Estes, and J. Scepan. 1990. An information systems approach to the preservation of biological diversity. *International Journal of Geographical Information Systems* 4:55-78.

Edwards, T.C., Jr., C.G. Homer, S.D. Bassett, A. Falconer, R.D. Ramsey, and D.W. Wright. 1995. Utah Gap Analysis: an environmental information system. Technical report 95-1. Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, Utah. Unpaged.

Franklin, J.F. 1992. Preserving biodiversity: species, ecosystems, or landscapes? *Ecological Applications* 3:202-206.

Gawler, S.C., J.J. Albright, P.D. Vickery, F.C. and Smith. 1996. Biological diversity in Maine: An assessment of status and trends in the terrestrial and freshwater landscape. Maine Natural Areas Program, Department of Conservation, Augusta, ME. 77 pp.

Gergely, K., J.M. Scott, and D. Goble. 2000. A new direction for the U.S. National Wildlife Refuges: the National Wildlife Refuge System Improvement Act of 1997. *Natural Areas Journal*, 20:107-118.

Habitat Acquisition Plan, Wildlife Division. In Press. Maine Department of Inland Fisheries and Wildlife.

Hepinstall, J.A., S.A. Sader, W.B. Krohn, R.B. Boone, and R.I. Bartlett. 1999. Development and testing of a habitat and land cover map of Maine. Maine Agriculture and Forest Experiment Station, Technical Bulletin 173, University of Maine, Orono. 104 pp.

Holling, C.S., and Meffe, G.K. 1996. Command and Control and the Pathology of natural resource management. *Conservation Biology* 10:328-337.

Hunter, ML., Jr. 1996. Fundamentals of Conservation Biology. Blackwell Science, Inc. Cambridge, MA. 482 pp.

Hunter, M.L., Jr., G.L. Jacobson, Jr., and T. Webb, III. 1988. Paleoecology and the coarse filter approach to maintaining biological diversity. *Conservation Biology* 2:375-385.

Hunter, M.L., Jr., and P. Yonzon. 1993. Altitudinal distributions of birds, mammals, people, forests, and parks in Nepal. *Conservation Biology* 7:420-423.

Irland, L.C. 1996. Wildness and wilderness in the northeastern United States: Challenge for the coming century. *International Journal of Wilderness* 2:27-30,48.

Izakson, O. 1999. Land in the balance: Maine environmentalists, property-rights activists, paper companies battle over public, private ownership. Bangor Daily News, February 27-28, 1999, A1.

Karl, J.W., J.M. Scott, and E. Strand. 1999. An assessment of Idaho's wildlife management areas for the protection of wildlife. Idaho Fish and Wildlife Cooperative Research Unit, University of Idaho, Moscow, Idaho. Unpaged.

Kellett, M.J. 1989. A New Maine Woods Reserve: Options for protecting Maine's northern wildlands. A report by The Wilderness Society, March 1989.

Knight, R.L. 1999. Private lands: The neglected geography. *Conservation Biology* 13:223-224.

Krebs, C.J. 1978. The experimental analysis of distribution and abundance. Harper and Row, New York, NY. 678 pp.

Krohn, W.B. 1996. Predicted vertebrate distributions from gap analysis: considerations in the designs of statewide accuracy assessments. Pages 147 – 162 in Scott, J.M., Tear, T.H., and F.W. Davis (editors). Gap Analysis: a Landscape Approach to Biodiversity planning. American Society for Photogrammetry and Remote Sensing, Bethesda, MD. 320 pp.

Krohn, W.B., K.D. Elowe, and R.B. Boone. 1995. Relations among fishers, snow, and martens: development and evaluation of two hypotheses. *The Forestry Chronicle* 71:97-105.

Krohn, W.B., R.B. Boone, S.A. Sader, J.A. Hepinstall, S.M Schaefer, and S.L. Painton. 1999. Maine Gap Analysis – a geographic analysis of biodiversity. Final contract report to USGS Biological Resources Division, Gap Analysis Program, Moscow, Idaho. 120 pp. plus appendices.

Krohn, W.B., R.B. Boone, and S.L. Painton. 1999. Quantitative delineation and characterization of hierarchical biophysical regions of Maine. *Northeastern Naturalist* 6(2):139-164.

Krohn, W.B. and R.D. Kelly, Jr. 1997. A conservation and public lands database for Maine: Project history and database documentation. Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono. 16 pp.

Leader-Williams, N., J. Harrison, and M.J.B. Green. 1990. Designing protected areas to conserve natural resources. *Scientific Progress Oxford* 74:189-204.

Leopold, A. 1933. Game Management. Charles Scribner's Sons. New York, New York. 481 pp.

Maddock, A. and G.A. Benn. 2000. Identification of conservation-worthy areas in northern Zulaland, South Africa. *Conservation Biology* 14:155-166.

Maine Atlas and Gazeteer, Fourteenth Edition, Delorme Mapping Company. 1989. Freeport, ME.

Maine Office of GIS (MOGIS). 1997. 1:24,000 Base Layers. Produced by the MOGIS for the Maine GIS Executive Council, 2 CD set (for more metadata information, see http://apollo.ogis.state.me.us).

Maine State Planning Office. 1997. Final Report and Recommendations of the Land Acquisition Priorities Advisory Committee. Submitted to Governor Angus S. King, Jr., November, 1997. 22 pp.

Margules, C.R. 1989. Introduction to some Australian developments in conservation evaluation. *Biological Conservation* 50:1-11.

Margules, C.R. 1999. Conservation planning at the landscape scale. Issues in Landscape Ecology. International Association for Landscape Ecology, Fifth World Congress, Snowmass Village, CO. 151 pp.

Margules, C.R., A.O. Nicholls, and M.B. Usher. 1994. Apparent species turnover, probability of extinction and the selection of nature reserves: a case study of the Ingleborough Pavements. *Conservation Biology*, 3:398-409.

Margules, C.R., A.O. Nichols, and R.L. Pressey. 1988. Selecting networks of reserves to maximise biological diversity. *Biological Conservation* 43: 663-676.

McKenzie, N.L., L. Belbin, C.R. Margules, and G.J. Keighery. 1989. Selecting representative reserve systems in remote areas: A case study in the Nullarbor region, Australia. *Biological Conservation* 50:239-261.

McMahon, J.S. 1990. The biophysical regions of Maine: patterns in the landscape and vegetation. M.S. Thesis, University of Maine, Orono. 119 pp.

National Research Council. 1993. Setting Priorities for Land Conservation. Committee for scientific and technical criteria for representative sample of natural diversity acquisition of lands for conservation. National Academy of Sciences, Washington, D.C. 262 pp.

Nichols, W.F., K.T. Killingbeck, and P.V. August. 1998. The influence of geomorphological heterogeneity on biodiversity II: A landscape perspective. *Conservation Biology* 12:371-379.

Nilsson, C., and F. Gotmark. 1992. Protected areas in Sweden: Is natural variety adequately represented? *Conservation Biology* 6:232-242.

Noss, R.F. 1983. A regional landscape approach to maintain diversity. *Bioscience* 33:700-706.

Noss, R.F. 1987. Protecting natural areas in fragmented landscapes. *Natural Areas Journal* 7:2-13.

Noss, R.F., and A.Y. Cooperider. 1994. Saving natures legacy: protecting and restoring biodiversity. Island Press, Washington, D.C., 416 pp.

Pimm, S.L. and J.H. Lawton. 1998. Planning for Biodiversity. *Science* 279:2068-2069.

Plantinga, A.J., T. Mauldin, and R.J. Alig. 1999. Land use in Maine: determinants of past trends and projections of future changes. Res. Pap. PNW-RP-511. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 20 pp.

Prendergast, J.R., R.M. Quinn, and J.H. Lawton. 1998. The gaps between theory and practice in selecting nature reserves. *Conservation Biology* 13:484-492.

Pressey, R.L. 1990. Reserve selection in New South Wales: where to form here? *Australian Zoologist* 26:70-75.

Pressey, R.L. 1992. Nature Conservation in Rangelands: lessons from research on reserve selection in New South Wales. *Rangeland Journal* 14:214-226.

Pressey, R.L. 1994. Ad Hoc Reservations: Forward or backward steps in developing representative reserve systems? *Conservation Biology* 8:662-668.

Pressey, R.L. and K.H. Taffs [In prep]. After representativeness: Additional criteria needed to measure progress in the coverage of protected areas, applied to western New South Wales. Draft provided to Stephanie Painton, University of Maine, Orono, Maine.

Pressey, R.L., C.J. Humphries, C.R. Margules, R.I. Vane-Wright, and P.H. Williams. 1993. Beyond opportunism: key principles for systematic reserve selection. *Trends in Ecology and Evolution* 8:124-128.

Pressey, R.L. and S.L. Tully. 1994. The cost of *ad hoc* reservation: A case study in western New South Wales. *Australian Journal of Ecology* 19:375-384.

Pressey, R.L. and V.S. Logan. 1994. Level of geographic subdivision and its effects on assessments of reserve coverage: A review of regional studies. *Conservation Biology* 8:1037-1046.

Schaefer, S.M. and W.B. Krohn. 2002. Testing predicted vertebrate occurrences from habitat associations: improving the interpretation of commission error rates. Pages 419-427. In Scott, J. M., P. J. Heglund, M. Morrison, M. Raphael, J. Haufler, B. Wall (editors). Predicting Species Occurrences: Issues of Scale and Accuracy. Island Press. Covello, CA. 868 pp.

Scott, J.M. 1999. A representative biological reserve system for the United States? *Society for Conservation Biology Newsletter* 6:1-9.

Scott, J.M. and B. Csuti. 1997. Noah worked two jobs. *Conservation Biology* 11: 1255-1257.

Scott, J.M, F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T.G. Edwards, Jr., J. Ulliman, and G.R. Wright. 1993. Gap Analysis: a geographic approach to protection of biological diversity. *Wildlife Monographs* 123:1-41.

Scott, J.M., F.W. Davis, R.G. McGhie, R.G. Wright, C. Groves, and J. Estes. 2001. Nature Reserves: Do they capture the full range of America's Biological Diversity? *Ecological Applications* 11(4):999-1007.

Soulé, M.E. 1991. Conservation: Tactics for a Constant Crisis. *Science* 253:744–749.

Stoms, D.M., F.W. Davis, K.L. Driese, K.M. Cassidy, and M.P. Murray. 1998. Gap Analysis of the vegetation of the intermountain semi-arid desert ecoregion. *Great Basin Naturalist* 58: 199-216.

Turner, M.G. 1990. Spatial and temporal analysis of landscape patterns. *Landscape Ecology* 4:21-30.

United States Fish and Wildlife Service web-site. *ftp://164.159.102.219/pub/refuges/metadata/metadata.html#Maine*

Wallace, J.M. and P.V. Hobbs. 1977. Atmospheric Science. Academic Press, New York, NY. 467 pp.

Wellnitz, T. and N.L. Poff. 2001. Functional redundancy in heterogeneous environments: implications for conservation. *Ecology Letters* 4:177-179.

Wessels, K.J., S. Frietag, and A.S. van Jaarsveld. 1999. The use of land facets as biodiversity surrogates during reserve selection at a local scale. *Biological Conservation* 89:21-38.

World Resources Institute. 1992. Global biodiversity strategy. World Resources Institute, Washington D.C. 244 pp.

Wright, D.H. 1983. Species-energy theory: an extension of species-area theory. *Oikos* 41:496-506.

Wright, R.G., and P.D. Tanimoto. 1998. Using GIS to prioritize land conservation actions: Integrating factors of habitat diversity, land ownership, and development risk. *Natural Areas Journal* 18:38-44.

APPENDIX

State Wildlife Management Areas and Other Wildlife Areas Managed by the Maine Department of Inland Fisheries and Wildlife and Federal National Wildlife Refuges Included in the Representational Analysis of Chapter 3.

Figure A.1. Location of State WMA's and other wildlife areas and Federal NWR's in Maine overlaid by major biophysical regions (modified from Krohn et al. 1999).

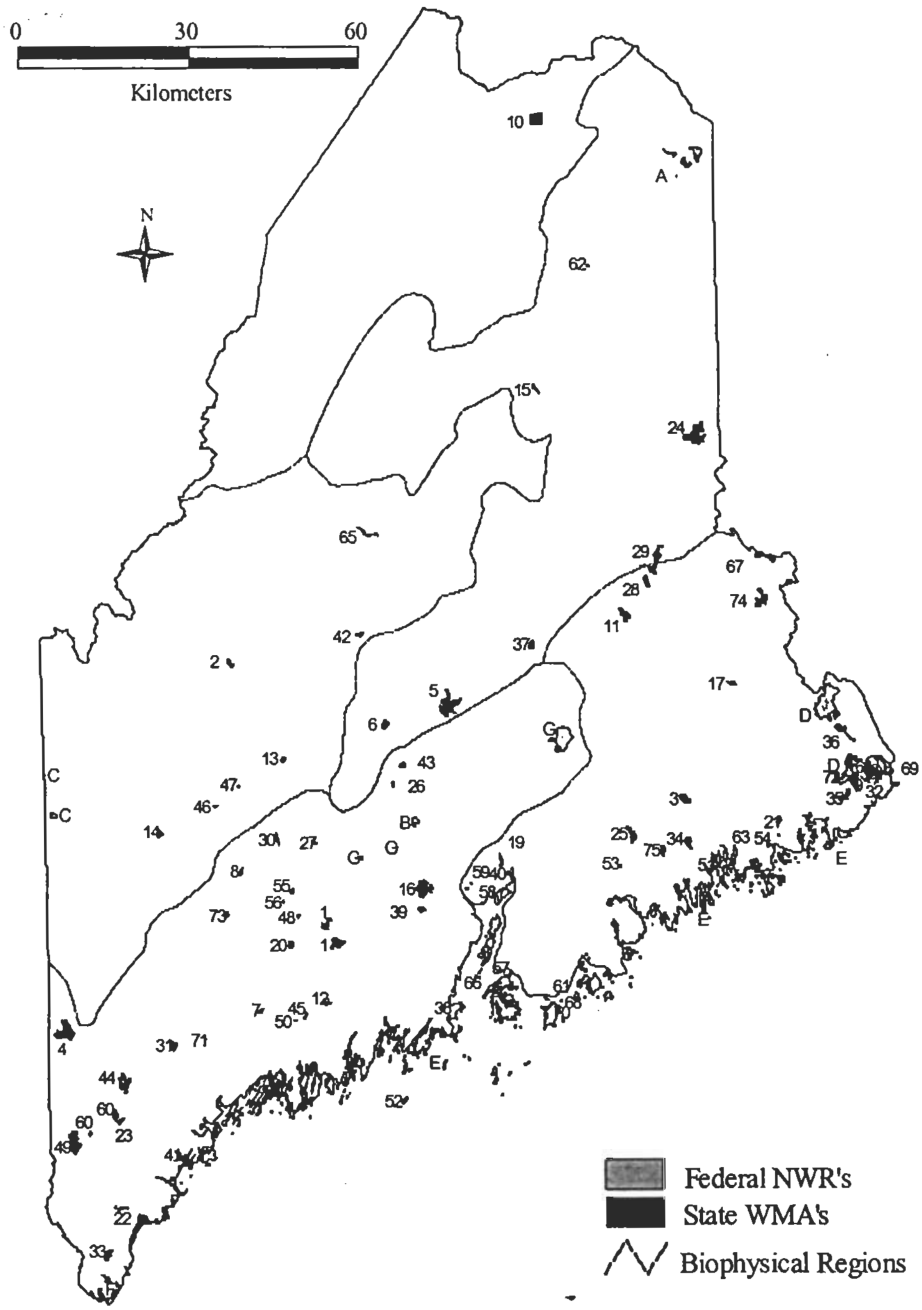


Table A.1. Number, name and area (km^2) of State Wildlife Management Areas and National Wildlife Refuges analyzed in Chapter 3.

State Wildlife Management Areas

No.	Name	Area (km^2)
1	Alonzo H. Garcelon WMA	16.5
2	Black Brook Flowage WMA	2.9
3	Bog Brook Flowage WMA	6.5
4	Brownfield Bog WMA	24.1
5	Bud Leavitt WMA	27.6
6	Cambridge WMA	3.8
7	Ceasar Pond WMA	1.8
8	Chesterville WMA	2.7
9	Commissary Point WMA	2
10	Dickwood Lake WMA	16.7
11	Dwinal WMA	8.7
12	Erle R. Kelley WMA	3.2
13	Fahi Pond WMA	1.2
14	Flagg WMA	2.7
15	Francis Dunn WMA	1.23
16	Frye Mountain WMA	21
17	Grand Lake Stream WMA	1.5
18	Horan Head WMA	0.9
19	Howard L. Mendall WMA	0.7
20	Jamies Pond WMA	2.5
21	Jonesboro WMA	2.1
22	Kennebunk Plains WMA	1.6
23	Killick Pond WMA	2.3
24	Lt. Gordon Manual WMA	27.1
25	Lyle Frost WMA	6
26	Madawaska WMA	0.95
27	Martin Stream WMA	0.95
28	Mattagodus Stream WMA	5.6
29	Mattawamkeag River WMA	16.8
30	Mercer Bog WMA	1.2
31	Morgan Meadow WMA	4.2
32	Morong WMA	2.2
33	Mt. Agamenticus WMA	4.8
34	Narraguagus WMA	6.4
35	Orange River WMA	2.9
36	Pennamaquam WMA	2.2
37	Pond Farm WMA	4
38	R. Waldo Tyler WMA	1.5
39	Ruffingham Meadow WMA	2.5
40	Sandy Point WMA	1.5
41	Scarborough WMA	12
42	Spectacle Pond WMA	2
43	St. Albans WMA	1.8
44	Steep Falls WMA	14.8
45	Steve Powell WMA	7
46	Strong WMA	0.4
47	Stump Pond WMA	0.2
48	Tyler Pond WMA	0.7
49	Vernon S. Walker WMA	18.4

Additional State wildlife areas analyzed:

50	Bachman	0.6
51	Back Bay	0.2
52	Eastern Duck Rocks	0.01
53	Egypt Bay	0.4
54	Englishmans River	0.3
55	Gawler	1.7
56	George Bucknam	0.4
57	Grass Ledge	0
58	Hurd Pond	1.2
59	Julie Lynn Robertson Wildlife Refuge	0.03
60	Little Ossippee River	6.3
61	Phoebe Ledge	0.01
62	Pleasant Acres	0.4
63	Pleasant River	0.1
64	Race Point	0.2
65	Roach River	3
66	Robinson's Rock	0.01
67	Spednik Lake	3.4
68	Spirit Lake	0.01
69	South Lubec Sand Bar	0.1
70	The Cow Pen	0.01
71	Thurston Meadow	0.4
72	Tide Mill Farm	6.4
73	Tolla Wolla	2.1
74	Tomah Stream Flowage	7.6
75	Tunk Lake	3.9

Table A.1. Continued.

National Wildlife Refuges

Letter	Name	Area (km^2)
A	Aroostook NWR	21.2
B	Carlton Pond NWR	4.2
C	Lake Umbagog NWR	4
D	Moosehorn NWR	10.4
E	Petit Manan NWR	22.8
F	Rachel Carson NWR	34.7
G	Sunkhaze Meadows NWR	44.3

BIOGRAPHY OF THE AUTHOR

Stephanie Orndorff was born in Indianapolis, Indiana, on April 18, 1974. In 1978, she moved with her family to Maitland, Florida, where she completed her high school education at Edgewater High School in Orlando, Florida.

Stephanie attended the University of Florida from 1993 – 1997, where she majored in Wildlife Ecology and Conservation with a specialization in Quantitative Studies. During those four years, she assisted on the USGS BRD Florida Gap Analysis Project. Working for the Department of Urban & Region Planning GEOPLAN Center, and 3001 Spatial Data Company she also gained valuable experience in GIS and Remote Sensing applications. In 1997, she began her graduate career at The University of Maine, Orono, Maine as a Research Assistant with the Maine Cooperative Fish and Wildlife Research Unit.

In 1999, Stephanie married Eric Orndorff and moved to Lancaster, Pennsylvania. From 1999 – 2001, she worked as a GIS Analyst for a private consulting company. In October 2001, she was hired by the University of Maryland Center for Environmental Science to work at the EPA's Chesapeake Bay Program Office in Annapolis, Maryland. Stephanie is a candidate for the Master of Science degree in Wildlife Ecology from The University of Maine in December, 2002.