Assessment of Ecoregional Spatial Patterns for National Wildlife Refuges of the Great Lakes Biology Network

R. Gregory Corace, III[1]
U.S. Fish and Wildlife Service, Seney National Wildlife Refuge
1674 Refuge Entrance Road, Seney, MI 49883

Lindsey M. Shartell
Independent Contractor, 20107 Frederick St., Houghton, MI 49931

Wayne L. Brininger, Jr.
U.S. Fish and Wildlife Service, Tamarac National Wildlife Refuge
35704 County Highway 26, Rochert, MN 56578

Richard S. King
U.S. Fish and Wildlife Service, Necedah National Wildlife Refuge
W7996 20th Street West, Necedah, WI 54646

[1]Corresponding author: Tel.: 906.586.9851x14, E-mail: Greg_Corace@fws.gov

Abstract

Knowledge of the existing geographic distribution of ownership, land covers, and other broad-scale features provides a basis for the prioritization of conservation and restoration actions in any strategic approach to conservation. Such understanding of geographic patterns can, for instance, help to identify conservation partners and where scale-appropriate land management actions should occur. For instance, in areas with large, contiguous public land ownerships, land managers may be more able to manage coarse-filter ecological processes such as prescribed or managed wildfire to meet ecosystem-based goals and objectives. We enhanced prior broad-scale assessments of the National Wildlife Refuge System by providing all refuges in the Great Lakes Biological Network (Network) a higher-resolution, ecoregional context for refuge-specific planning and management. We used multiple spatial data sources in a geographic information system (GIS) to depict patterns associated with 14 Network refuges and their 15 broader-scaled ecoregions. Spatial data pertaining to ownership, land cover, and soils were used to assess conditions among ecoregions of the Network and individual refuges. We also conducted analyses of landscape metrics using land cover data at both of these scales. Although more consideration of the observed patterns is warranted and some discrepancies in the data sources were found, preliminary findings indicate that considerable variability exists among ecoregions and refuges in all characteristics studied, although finer-scaled groupings are possible with some refuges (e.g., Shiawassee and Ottawa NWRs; Tamarac-Rice Lake-Necedah-Seney NWRs, etc.). Larger refuges tended to be in ecoregions with more public lands characterized by more natural land covers. In these refuges, we suggest the broad-scale conservation or restoration of natural patterns and processes is possible, with other public agencies comprising the dominant conservation partners. In other refuges in other ecoregions, attempts can be made to mitigate the adverse impacts of non-native land covers on primarily private lands that dominate these ecoregions. Conservation partners of note may be conservancies and other conservation-oriented private entities. The patterns we found indicate that each refuge must be viewed as having its own opportunities and limitations for wildlife habitat conservation and restoration.

Introduction

Geographically broad-scale analyses are important because many ecological patterns only become obvious at broader scales and because biological diversity must be considered at the broadest scales possible (Urban et al. 1987, O'Connor et al. 1996, Askins 2000). Moreover, because alterations to the geographic distribution, abundance, structure, and composition of land covers and their finer-resolution ecosystem types are implicated in the declines of many wildlife species, knowledge of their existing geographic distribution provides a first cut approximation for the prioritization of conservation and restoration actions. Such patterns are of interest to wildlife conservationists, in particular, because many species of wildlife respond to habitat variables at relatively broad scales (O'Connor et al. 1996, Askins 2000, Ribic et al. 2009).

An assessment that compares and contrasts land cover and other landscape features at ecoregional scales and across ownerships should provide useful information for refuge planning since refuges must not only consider the ecological patterns and processes within their boundaries, but outside as well. The purpose of this project is to enhance the prior assessment of Scott et al. (2004) that characterized patterns among National Wildlife Refuges of the Lower 48 states. In doing so, this assessment provides all refuges in the Great Lakes Biological Network (Network) a higher-resolution, ecoregional context for refuge-specific planning and management. This assessment also begins to answer some questions pertinent to the Strategic Habitat Conservation approach of the U.S. Fish and Wildlife Service: 1) which conservation filters (Hunter 2005) are most appropriate on which refuges?; 2) which refuges seem most similar in the observed patterns and therefore may be able to share resources and expertise?; and 3) to what degree should a standardized approach to conservation be applied to refuges and their associated ecoregions.

Study Area and Methods

We used multiple spatial data sources (Table 1) in a geographic information system (GIS) to depict patterns associated with 14 Network refuges and their associated 15 ecoregions (Fig. 1, Tables 2-4). The ecoregion layer, maintained by the U.S. Forest Service (USDA Forest Service 2007), was used as the base layer for most ecoregional analyses. At the ecoregion scale, ownership, land cover, and soils were assessed by determining the percent and acreage of each type. Ownership patterns for ecoregions of Ohio, Michigan, and Wisconsin were determined from the Conservation and Recreation Lands (CARL) dataset (unknown year). These data did not include Minnesota, for which MN GAP Stewardship data (2008) were used. The CARL dataset classified ownership into six categories (federal, state, county, local, NGO, and private) based on value to conservation. During analysis those areas not included in the dataset were categorized as 'no data'. Much of the ownership in this category was assumed to be private lands. MN Gap Stewardship data was classified into nine categories (federal, state, county, other public, private, private conservancy, private industrial, private non-

industrial, and tribal). We used 2001 National Land Cover Data (USGS 2001) to quantify ecoregion composition (see Appendix 1 for class definitions). Minimum mapping units for NLCD was 2 acres. The U.S. General Soil Map (STATSGO2, NRCS) from the National Resources Conservation Service was used to determine soil types. For areas where STATSGO2 data was not available, soil type was classified as unknown. Maps of ownership and land cover were created for ecoregions to show the extent and distribution of each across the landscape. Only patterns for ecoregions with ≥15% of a refuge within their boundaries were assessed. Most refuges were associated with one dominant ecoregion, but a few had secondary ecoregions or included water. In the case of Detroit River International Wildlife Refuge, the dominant ecoregion for this study was considered to be the Western Paleozoic Plateau, despite a slight majority of the refuge being comprised of water.

At the refuge scale, land cover and soils were assessed by determining the percent cover and acreage of each type. However, maps were created for only land cover. At both the ecoregion and landscape scales, landscape metrics (Table 5) based on land cover were calculated using the program FRAGSTATS (McGarigal et al. 2002). Landscape metrics provide a means of quantifying important landscape attributes, and lend themselves to informing land management decisions (Forman and Godron 1986, Rogers 1987). Landscape metrics are also important when considering wildlife habitat, especially for area-sensitive species (Ribic et al. 2009). In this assessment, landscape metrics were used to evaluate the heterogeneity of the land (number of patches, patch richness, patch density, Simpson's diversity, Shannon's evenness, Simpson's evenness) and the intensity of fragmentation (largest patch index, landscape shape index, mean patch area, Shannon's diversity). For the sake of brevity, comparisons between refuges and their associated ecoregions were made for only three variables: landscape shape index, patch density, and mean patch area. [Note: some ecoregions (e.g., Door Peninsula) and refuges (e.g., Green Bay NWR, Whittlesey Creek NWR, etc.) comprise significantly less area than others, and therefore were often excluded from discussion. This treatment is not in any way mean to devalue the conservation value of these land units.]

Results

[Note: during our analyses, data discrepancies were found and results should be viewed with some caution. For instance, some ownership discrepancies seem to exist for the ecoregion containing Necedah NWR; refuge lands are listed as local ownership, not federal. At Sherburne NWR, NLCD depicted considerable cultivated crop. This is likely misinterpretation of open conditions possibly induced by prescribed fire.]

Ecoregional Ownership Patterns

Ownership patterns differed considerably among ecoregions of the Network. When lumped into two broad categories (i.e., public and private lands), the majority (79%, or 12 of 15) of the ecoregions had <50% area in public ownership. Seney Lake Plain (Seney NWR) had the greatest percentage of area in

public lands, at nearly 80%, with Kirtland's Warbler High Sand Plains (Kirtland's Warbler WMA) and Toimi Uplands (Rice Lake NWR) the only other ecoregions with >50% of the land area in public ownership. Six ecoregions had between 10-50% area in public ownership, while five had <10% area in public lands. The Western Paleozoic Plateau ecoregion (Ottawa NWR and Detroit River IWR) was comprised of the least public land (Fig. 2 and Appendices 2, 3).

Ecoregional Land Cover

Of the 21 distinct land cover classes, 15 were present in ecoregions of the Network. Natural land covers (i.e., land covers comprised of non-anthropogenic vegetation, such as different forest types, different wetland types, etc.) were dominant (>50% area) in nine of the 15 ecoregions (60%). Of all NLCD types, forest land cover types were the dominant land cover in most of these ecoregions. Those ecoregions with <10% area in public lands were generally also the ecoregions with the most anthropogenic land covers. In these ecoregions, cultivated crops comprised between 20-60% area (Figs. 3, 4 and Appendices 4, 5).

Ecoregional Soils

Ecoregional soils mirrored ecoregional land cover to a considerable degree. Over 450 different soil types were found among the ecoregions of study, among a number of different soil series (Appendix 6). Some ecoregions were predominately comprised of well-drained soils (e.g., Kirtland's Warbler High Sand Plains, Mille Lacs Uplands, Pine Moraine and Outwash Plains), while other ecoregions were comprised of more poorly-drained soils (e.g., Maumee Lake Plain, Saginaw Clay Plain, Seney Lake Plain), while still others were more mixed (e.g., Anoka Sand Plain, Central Wisconsin Sand Plain).

Refuge Land Cover

Even at the coarse resolution of NLCD, Network refuges comprise an array of land covers. In concert with their associated soil types (see below), most (86%, or 12 of 14) Network refuges had considerable area in wetland land covers (e.g., emergent herbaceous wetlands, woody wetlands). Forest land covers other than woody wetlands were found on 71% (10) of these refuges, with deciduous forests being the most commonly encountered. Tamarac and Rice Lake NWRs were the most similar in composition, with Kirtland's Warbler WMA being unlike the other refuges in that it is almost entirely comprised of upland (and mostly forested) land covers (Fig. 5 and Appendices 7, 8).

Refuge Soils

Soil patterns varied greatly among refuges, but refuge soil series tended to be more dominated by poorly-drained soils than surrounding ecoregions overall. That said, many refuge soils are well drained to excessively well drained, suggesting droughty conditions and limitations for some management (Appendix 9).

Ecoregional and Refuge Landscape Metrics

All ecoregions, except the smallest (Door Peninsula) had patch richness (PR) values of 15, representing the total number of land cover types found overall in this assessment. Only two ecoregions (Door Peninsula and Anoka Sand Plain, ecoregions of Sherburne and Crane Meadows NWRs) had patch density (PD) of >20 patches / 100 ha (247 ac); PD averaged 15.82 (±4.70). Excluding the outlier Door Peninsula, the largest patch indices (LPIs) were found in Pine Moraine and Outwash Plain (ecoregion of Tamarac NWR) and St. Louis Moraines (ecoregion of Rice Lake NWR), suggesting less heterogeneous or more "unified" ecoregions. Other than these three ecoregions, all other ecoregions had LPIs <7.50 (Appendices 10, 11). Among Network refuges, PR ranged from 15 (Shiawassee NWR) to 5 (Cedar Point NWR) and averaged 11.14 (±4.70). PD ranged from 54.37 (Whittlesey Creek NWR) to 2.47 (Cedar Point NWR); average PD was 20.84 (±13.72). LPI ranged from 65.89 (Cedar Point NWR) to 4.19 (Kirtland's Warbler WMA) and averaged 28.30 (±20.36) (Appendix 12).

Landscape shape index (LSI, a measure of the percent deviation from a circle) was greater for all ecoregions than it was for refuges, illustrating the relative more natural spatial patterns found on refuges relative to the surrounding lands that had more linear features such as roads and powerlines (Fig. 6 and 7). Including all refuge lands in all ecoregions, 11 (73%) of the refuges had approximately the same or greater mean patch area, relative to their ecoregion (Fig. 8). However, when only refuges with >35% refuge area in a given ecoregion are compared to their associated ecoregion, Horicon, Rice Lake, Tamarac, and Sherburne NWRs are generally the only ones comprised of larger patches than the surrounding ecoregion, with Seney NWR quite representative of the Seney Sand Lake Plain ecoregion (Fig. 9). Ottawa NWR seemed to be the most dissimilar with its ecoregion, with average patch area of the refuge 9.82 ha (24.25 ac) and that of the ecoregion 14.62 ha (36.11 ac). For most ecoregions and Network refuges, patch density (PD) did not drastically differ, as there was almost an even split of refuges with more or less PD than their surrounding ecoregion (Fig. 10 and 11).

Conservation Implications

The U.S. Fish and Wildlife Service National Wildlife Refuge System (NWRS) represents our nation's attempt to conserve, preserve, and restore lands for the wildlife they support. However, at many refuges (and within many of their associated ecoregions) existing patterns are considerably altered relative to pre-European settlement (i.e., benchmark) conditions (Noss 2004). To guide land management actions within the NWRS, the *1997 Refuge Improvement Act* stipulated that mangers should, "where appropriate, restore and enhance, healthy populations of fish, wildlife, and plants…." (Public Law 105-57-October 9, 1997). Along with the subsequent Biological Integrity Policy (2001), these two documents directed land managers to favor ecologically-based habitat management, with restoration to historic conditions where and when possible (Schroeder et al. 2004, Meretsky et al.

2006). However, without consideration of surrounding spatial patterns, refuge land management is done within a void. Thus, a spatially broad, ecoregional context that takes into account spatial patterns in land ownership and land cover is needed to guide finer-scaled land management decisions. Such a top-down, multi-scale approach can be used to identify where conservation and restoration efforts may be most effective, and where potential partners may be needed to meet broader NWRS goals and objectives.

To provide context to future land management across a gradient of conservation filters (Hunter 2005), we compared and contrasted spatial patterns among Network ecoregions and their associated refuges. Although more consideration of the observed patterns is warranted, preliminary findings indicate that considerable variability exists among ecoregions and refuges in all characteristics studied. A few large refuges were found in ecoregions with mostly public lands characterized by more natural land covers, but most Network refuges exist in a private lands matrix with agricultural and other anthropogenic land covers. In the former refuges, we suggest that “coarse-filter” and “meso-filter” conservation strategies to provide wildlife habitat (Hunter 2005) seem to fit these refuges, as the conservation and restoration of ecological patterns (e.g., native plant communities) and processes (e.g., broad-scale prescribed fire) may be more likely and the relatively fewer conservation partners more accepting of such approaches. Conversely, on smaller refuges that reside in a matrix of private lands, attempts can be made to mitigate the adverse impacts of non-native land covers and land use that may be adverse to many wildlife species. Conservation partners of note may be smaller conservancies and other conservation-oriented private entities (e.g., hunting clubs), with a greater focus on “meso-filtered” and “fine-filtered” conservation strategies of specific habitat features (e.g., structure of forests for stop-over habitat during migration) or wildlife species.

Based on our limited analyses, soil and land cover patterns on refuges mirrored one another to a considerable degree. That said, on some refuges the soils patterns do not necessarily coincide exceptionally well with some past management options. For instance, Seney NWR (formerly, Seney National Waterfowl Refuge) was established in 1935 by Executive Order under the *Migratory Bird Conservation Act* for the protection and production of migratory birds and other wildlife. Much of the history of Seney has therefore been devoted to waterfowl production through an anthropogenic pool system (USFWS 2009). However, soils at Seney (as shown here) tend to be sandy, and of relatively low nutrient value and low productivity. Consequently, waterfowl production has been less than stellar for many (but not all) waterfowl species using the anthropogenic pool system. On this and other refuges, future management may benefit from a top-down approach to habitat management works within the inherent land capabilities dictated by soils and related ecological disturbances (see Seymour and Hunter 1999, Burger and Kotar 2003, etc.).

Our analysis of landscape metrics also has a number of conservation implications. First, patch richness (PR, or the diversity of different patch types) showed relatively little variability across ecoregions, but did show variability at the refuge-scale. Unfortunately, this refuge-level diversity may be counter-productive as some refuges may have tried in the past to maximize habitat diversity to the detriment of natural patterns and processes (Schroeder et al. 2004, Scott et al. 2004). Refuges should carefully evaluate the relative value of all their land covers and determine whether some can be better provided for by surrounding lands. Such a process was done at Seney NWR (USFWS 2009) and because surrounding lands provided an abundance of anthropogenic “old field” conditions, managers made the choice to rehabilitate most small field patches to forest patches, thereby also enhancing mean patch size of adjacent forests. Managing for fewer, but larger natural patches may have considerable utility for Network refuges.

Our analysis of landscape shape indices (LSI) incorporates a number of important features of wildlife habitat planning and management. LSI provides an evaluation of the perimeter to edge ratio of discrete patches of land cover. Greater LSI values indicate patches that exceed the reference value for a circle, the geometric patterns that maximizes area relative to perimeter (Rogers 1987). In our analysis, all refuges had LSI values less than the surrounding ecoregion. In other words, from a spatial perspective, Network refuges provide patches with generally more interior habitat area relative to perimeter (or edge) habitat area than the surrounding lands. The greatest discrepancies between ecoregional and refuge LSI was found for the ecoregions containing Tamarac NWR. Patches within the refuge likely provide habitat for area-sensitive species better than the surrounding agricultural-forest matrix and its abundant linear features. Conversely, at Seney NWR a relatively high LSI was found, likely the result of both glacial patterns in the wetland-dominated area (including the largest patterned fen in the Lower 48 States) and the anthropogenic pool system. Where possible, future management on refuges should strive for larger patches with greater interior area as surrounding lands often provide considerable edge habitat already.

The spatial patterns we found indicate that each Network refuge must be viewed as having its own opportunities and limitations for wildlife habitat conservation and restoration, although finer-scaled groupings of refuges are possible (e.g., Shiawassee-Detroit River-Ottawa NWRs share many spatial patterns; Tamarac-Rice Lake-Necedah-Seney NWRs share many other spatial patterns, etc.). Future work should refine this assessment by describing natural disturbance regimes associated with different land covers in each ecoregion and refuge, and identify high-priority conservation areas based on distribution and abundance patterns of rare communities, species, and/or ecological processes.

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Works Cited

Askins, R.A. 2000. Restoring North America's birds: lessons from landscape ecology. Yale University Press, New Haven, CT.

Burger, T.L. and J. Kotar. 2003. A guide to forest communities and habitat types of Michigan. The Department of Forest Ecology and Management, University of Wisconsin, Madison, WI.

Ducks Unlimited, Inc. Conservation and Recreation Lands (CARL). Unknown year. Available online: http://www.ducks.org/Conservation/GLARO/3750/GISCARL.html

Forman, R.T.T. and M. Godron. 1986. Landscape Ecology. John Wiley & Sons, New York.

Hunter, M.L., Jr. 2005. A mesofilter conservation strategy to complement fine and coarse filters. Conservation Biology 19:1025-1029.

McGarigal, K., S.A. Cushman, M.C. Neel and E. Ene. 2002. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. University of Massachusetts, Amherst. Available online: http://www.umass.edu/landeco/research/fragstats/fragstats.html .

Meretsky, V.J., R.L. Fischman, J.R. Karr, D.A. Ashe, J.M. Scott, R.F. Noss and R.L. Schroeder. 2006. New directions in conservation for the National Wildlife Refuge System. BioScience 56:135-143.

Minnesota Department of Natural Resources. GAP Stewardship 2008. Available online: http://www.lmic.state.mn.us/chouse/land_own_general.html

Natural Resources Conservation Service, United States Department of Agriculture. U.S. General Soil Map (STATSGO2). Available online: http://soildatamart.nrcs.usda.gov.

Noss, R.F. 2004. Some suggestions for keeping National Wildlife Refuges healthy and whole. Natural Resources Journal 44:1093-1111

O'Connor, R.J., M.T. Jones, R.B. Boone and T.B. Lauber. 1996 Linking continental climate, land use, and land patterns with grassland bird distribution across the conterminous United States. Studies in Avian Biology 19:45-59.

Ribic, C.A., R.R. Koford, J.R. Herkert, D.H. Johnson, N.D. Niemuth, D.E. Naugle, K.K. Bakker, D.W. Sample and R.B. Renfrew. 2009. Area sensitivity in North American grassland birds: patterns and processes. The Auk 126:233-244.

Rogers, C.A. 1987. Describing landscapes: indices of structure. M.S. Thesis, Simon Fraser University, Burnaby, BC, Canada.

Schroeder, R.L., J.I. Holler and J.P. Taylor. 2004. Managing National Wildlife Refuges for historic and non-historic conditions: determining the role of the refuge in the ecosystem. Natural Resources Journal 44:1185-1210.

Scott, J.M., T. Loveland, R. Gergely, J. Strittholt and N. Staus. 2004. National Wildlife Refuge System: ecological context and integrity. Natural Resources Journal 4:1041-1066.

Seymour, R.S. and M.L. Hunter, Jr. 1999. Principles of ecological forestry. Ch. 2 (p. 22-61) In: Managing biodiversity in forest ecosystems. M.L. Hunter, Jr., editor. Cambridge University Press, Cambridge, UK.

Urban, D.L., R.V. O'Neill and H.H. Shugart, Jr. 1987. Landscape ecology. Bioscience 37:119-127.

USDA Forest Service. 2007. Bailey's Ecoregions and Subregions of the United States, Puerto Rico, and the U.S. Virgin Islands. National Atlas of the United States, Reston, VA.

USGS. National Land Cover Database 2001 (NLCD 2001) Available online: http://www.mrlc.gov/mrlc2k_nlcd.asp.

USFWS. 2009. Seney National Wildlife Refuge Comprehensive Conservation Plan. Regional Office, Fort Snelling, MN.

Table 1. Geographic information system data layers and scales of interest in this assessment.

Theme	Data	Source	Scale
Ecoregion Subsections	U.S. Forest Service Ecoregions	USFS	Ecoregion
Refuge Boundary	Region 3 Boundary	FWS	Refuge
Land Cover	2001 National Land Cover Data (NLCD)	USGS	Ecoregion, Refuge
Soil	U.S. General Soil Map (STATSGO2)	NRCS	Ecoregion, Refuge
Ownership	Conservation and Recreation Lands (CARL)	Ducks Unlimited	Ecoregion
Ownership	Minnesota GAP Stewardship	Minnesota DNR	Ecoregion

Figure 1. Major refuges of the Great Lakes Biology Network (GLBN) and their associated ecoregions. Island refuges are not shown and are not included as part of this assessment.

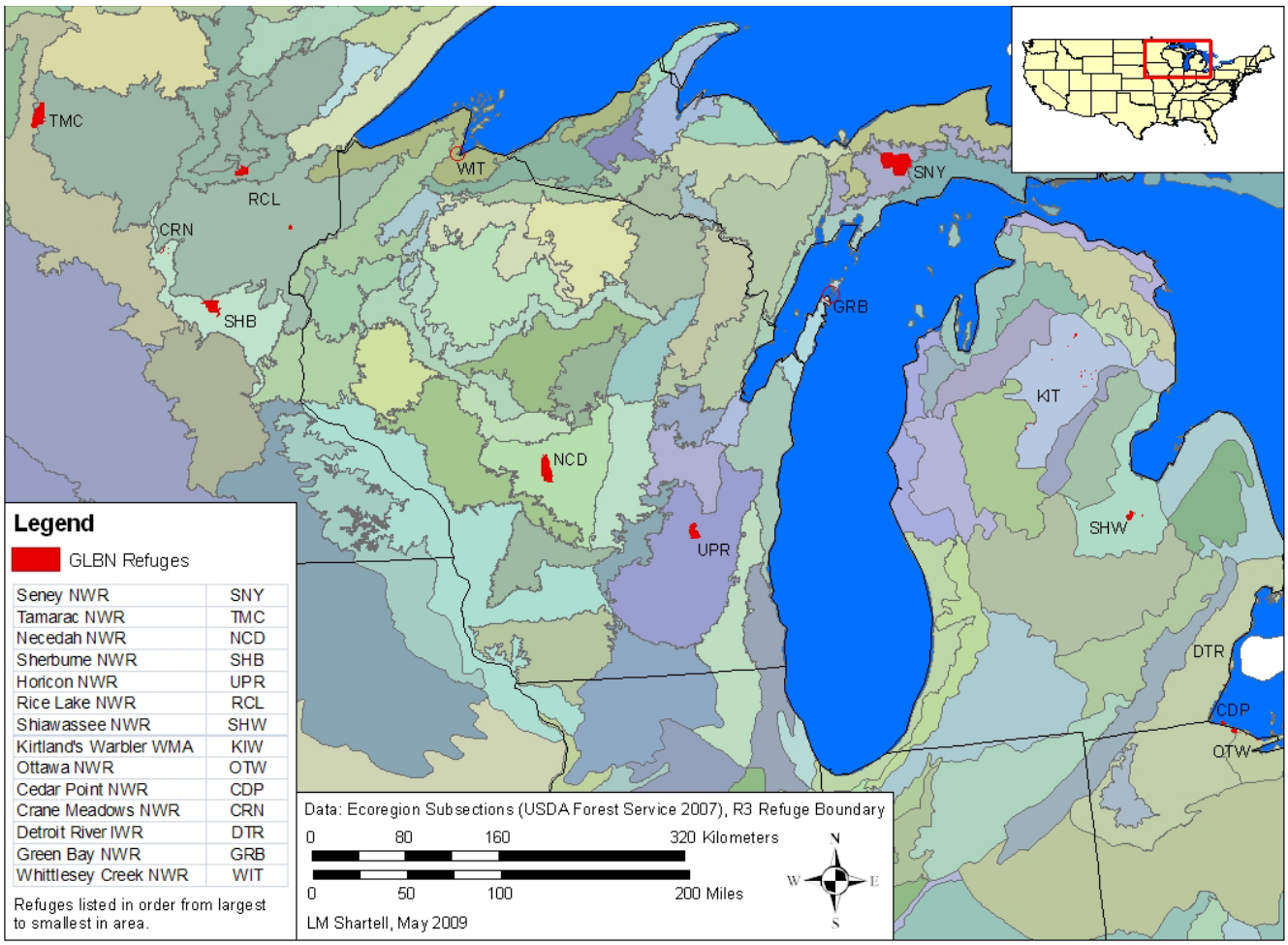


Table 2. Major refuges of the Great Lakes Biology Network, listed in ranked order by area.

Refuge	Code	State	Acres
Seney National Wildlife Refuge	SNY	MI	95,376.50
Tamarac National Wildlife Refuge	TMC	MN	44,319.61
Necedah National Wildlife Refuge	NCD	WI	43,868.62
Sherburne National Wildlife Refuge	SHB	MN	30,835.75
Horicon National Wildlife Refuge	UPR	WI	21,848.93
Rice Lake National Wildlife Refuge	RCL	MN	20,237.21
Shiawassee National Wildlife Refuge	SHW	MI	9,558.74
Kirtland's Warbler Wildlife Management Area	KIW	MI	6,601.68
Ottawa National Wildlife Refuge	OTW	OH	5,932.98
Cedar Point National Wildlife Refuge	CDP	OH	2,603.06
Crane Meadows National Wildlife Refuge	CRN	MN	1,579.97
Detroit River International Wildlife Refuge	DTR	MI	1,450.37
Green Bay National Wildlife Refuge	GRB	WI	323.19
Whittlesey Creek National Wildlife Refuge	WIT	WI	292.19

Table 3. Ecoregions associated with major refuges of the Great Lakes Biology Network, listed in ranked order by area.

Ecoregion subsection	Acres
Mille Lacs Uplands	3,834,727.24
Western Paleozoic Plateau	3,503,038.41
Alexandria Moraine-Hardwood Hills	3,496,625.69
Pine Moraine and Outwash Plains	3,026,574.88
Southern Green Bay Lobe	2,783,311.51
Kirtland's Warbler High Sand Plains	1,881,709.76
St. Louis Moraines	1,649,086.82
Central Wisconsin Sand Plain	1,616,996.43
Toimi Uplands	1,514,914.69
Saginaw Clay Lake and Till Plain	1,311,794.84
Superior-Ashland Clay Plain	1,303,647.11
Anoka Sand Plain	1,200,852.70
Seney Lake Plain	884,246.69
Maumee Lake Plain	458,200.12
Door Peninsula	301.40

Table 4. Percentage of ecoregional area in major refuges of the Great Lakes Biology Network.

Refuge and associated ecoregion(s)	Acres of refuge in ecoregion	Percent of refuge in ecoregion
CEDAR POINT NATIONAL WILDLIFE REFUGE		
Western Paleozoic Plateau	1,913.14	73.50
Water	689.92	26.50
CRANE MEADOWS NATIONAL WILDLIFE REFUGE		
Anoka Sand Plain	1,579.97	100.00
DETROIT RIVER INTERNATIONAL WILDLIFE REFUGE		
Western Paleozoic Plateau	719.00	49.57
Water	731.37	50.43
GREEN BAY NATIONAL WILDLIFE REFUGE		
Door Peninsula	297.28	91.98
Water	25.91	8.02
HORICON NATIONAL WILDLIFE REFUGE		
Southern Green Bay Lobe	21,848.93	100.00
KIRTLANDS WARBLER WILDLIFE MANAGEMENT AREA		
Kirtland's Warbler High Sand Plains	6,362.36	96.37
Presque Isle Lake and Till Plains	239.33	3.63
NECEDAH NATIONAL WILDLIFE REFUGE		
Central Wisconsin Sand Plain	43,868.62	100.00
OTTAWA NATIONAL WILDLIFE REFUGE		
Maumee Lake Plain	4,102.55	69.15
Western Paleozoic Plateau	1,803.60	30.40
Water	26.83	0.45
RICE LAKE NATIONAL WILDLIFE REFUGE		
St. Louis Moraines	15,213.39	75.18
Toimi Uplands	2,950.77	14.58
Mille Lacs Uplands	2,073.05	10.24
SENEY NATIONAL WILDLIFE REFUGE		
Seney Lake Plain	94,063.57	98.62
St. Ignace Lake Plain	1,312.93	1.38
SHERBURNE NATIONAL WILDLIFE REFUGE		
Anoka Sand Plain	29,835.65	96.76
Mille Lacs Uplands	1,000.10	3.24
SHIAWASSEE NATIONAL WILDLIFE REFUGE		
Saginaw Clay Lake and Till Plain	9,558.74	100.00
TAMARAC NATIONAL WILDLIFE REFUGE		
Pine Moraine and Outwash Plains	37,371.27	84.32
Alexandria Moraine-Hardwood Hills	6,948.34	15.68
WHITTLESEY CREEK NATIONAL WILDLIFE REFUGE		
Superior-Ashland Clay Plain	287.86	98.52
Water	4.34	1.48

Table 5. Landscape metrics, their descriptions, units of measurement, and conservation-related questions.

Metric	Code	Description	Units	Questions Addressed
Number of patches	NP	Total number of patches	-	How heterogeneous is land unit?
Patch richness	PR	Number of patch types on a landscape	-	How heterogeneous is land unit?
Patch density	PD	Number of patches per unit area	#/100 ha	How heterogeneous is land unit?
Largest patch index	LPI	Area of the largest patch of the corresponding patch type divided by total landscape area	%	How fragmented? What impact on area-sensitive species?
Landscape (class) shape index	LSI	Measures the complexity of patch shape compared to a standard shape (square or almost square) of the same size; percentage in which the element in question exceeds the perimeter of the reference shape (circle)	%	How fragmented? What impact on area-sensitive species?
Mean patch area (landscape grain size)	AREA _MN	Mean patch size of all patches on a landscape	ha	How fragmented? What impact on area-sensitive species?
Shannon's diversity index	SHDI	The amount of uncertainty associated with predicting the class of a randomly sampled patch	-	How fragmented? What impact on area-sensitive species?
Simpson's diversity index	SIDI	Probability of choosing two individuals that do not belong to the same class	-	How heterogeneous is land unit?
Shannon's eveness index	SHEI	Ratio of the observed index of diversity to the maximum value that diversity could assume	-	How heterogeneous is land unit?
Simpson's eveness index	SIEI	Ratio of the observed index of diversity to the maximum value that diversity could assume	-	How heterogeneous is land unit?

Fig. 2. Percentage of area in each ecoregion in two general ownership categories: public (e.g., local, county, state, federal, and unknown) and private (e.g., non-government organization, private conservancy, private non-industrial, private, tribal, no data). Because it contains significantly less area than the other ecoregions, data for the Door Peninsula should be viewed with caution.

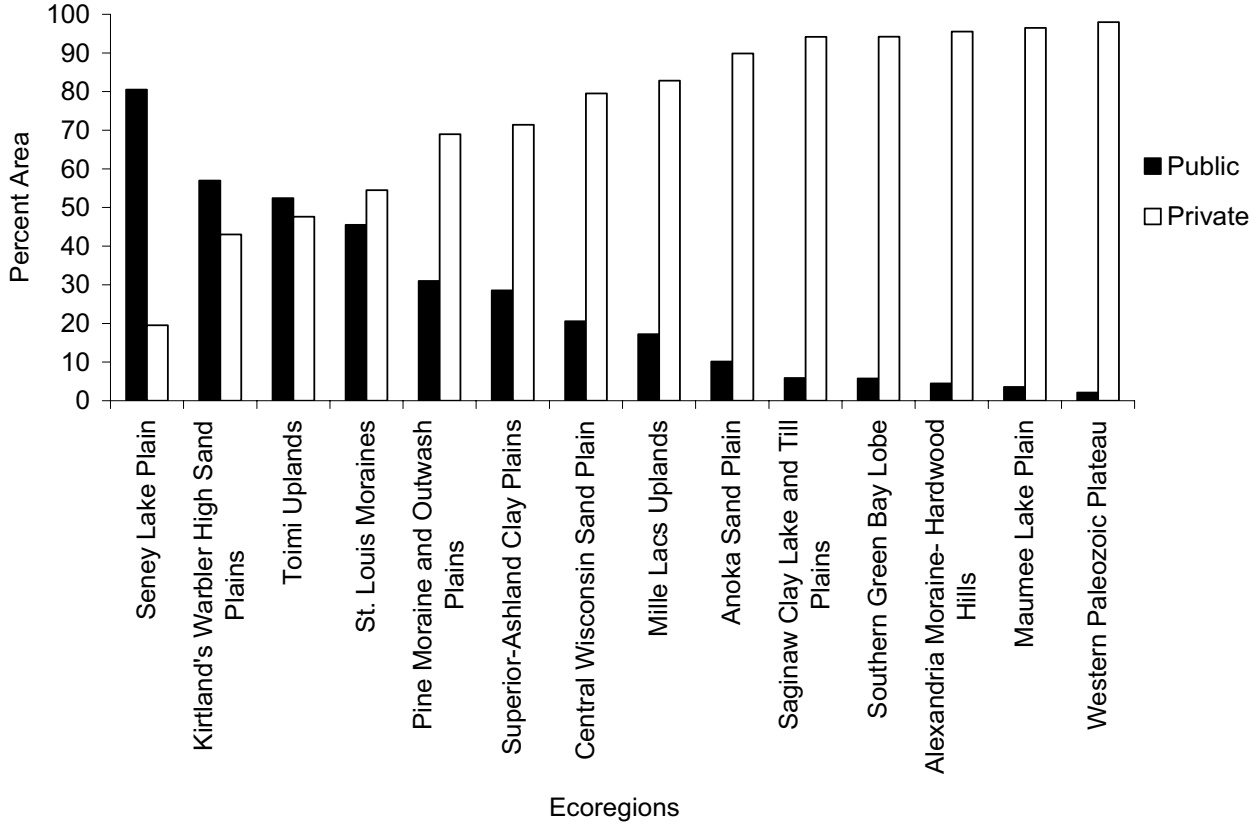


Fig. 3. Percentage of each ecoregion of the Great Lakes Biology Network in natural land covers (top) and anthropogenic land covers (bottom). Because it contains significantly less area than the other ecoregions, data for the Door Peninsula should be viewed with caution.

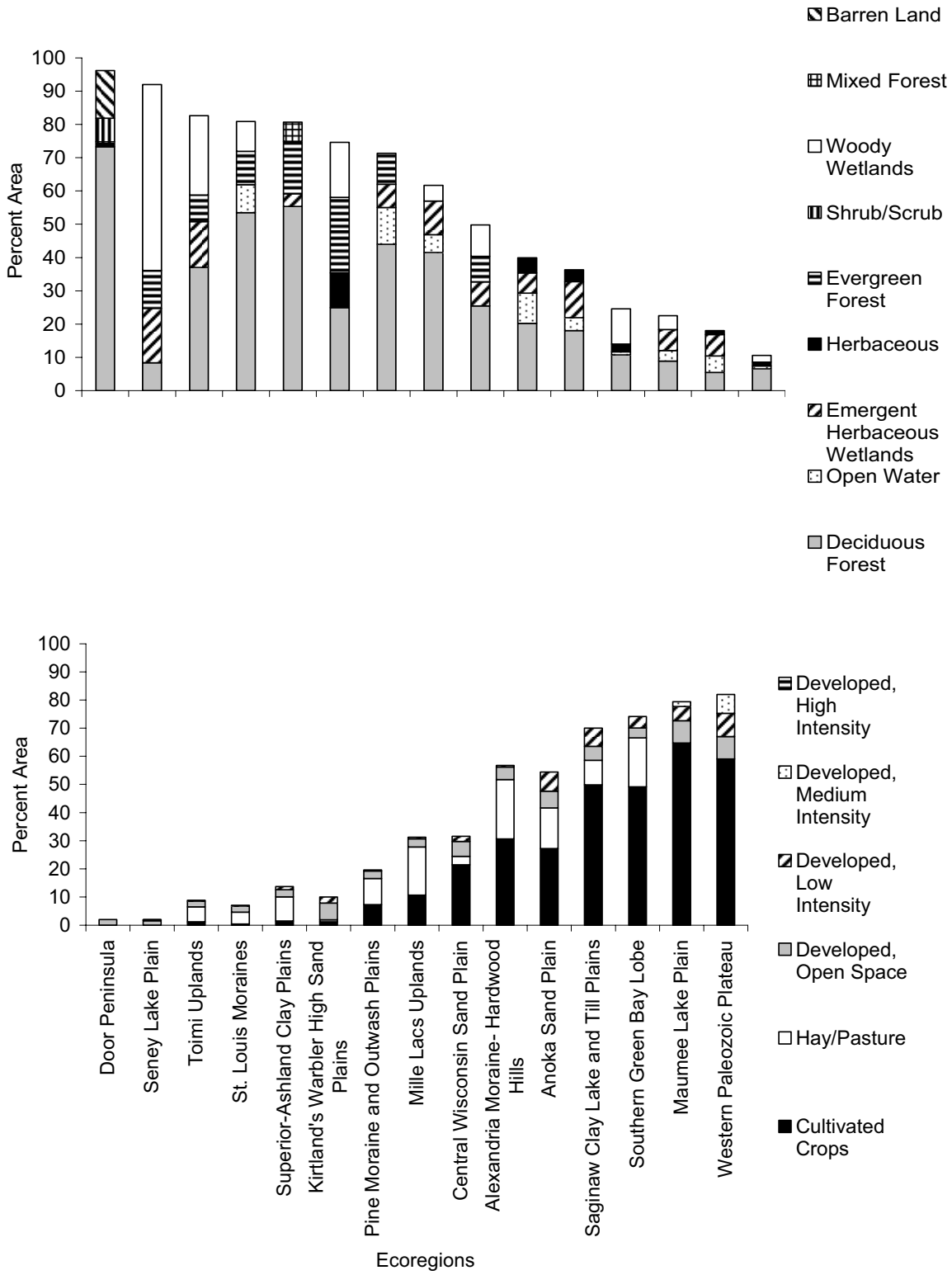


Fig. 4. Percentage of each ecoregion of the Great Lakes Biology Network in different land covers. Names of associated refuges are shown with each. Ecoregions (x-axis) are listed in alphabetical order.

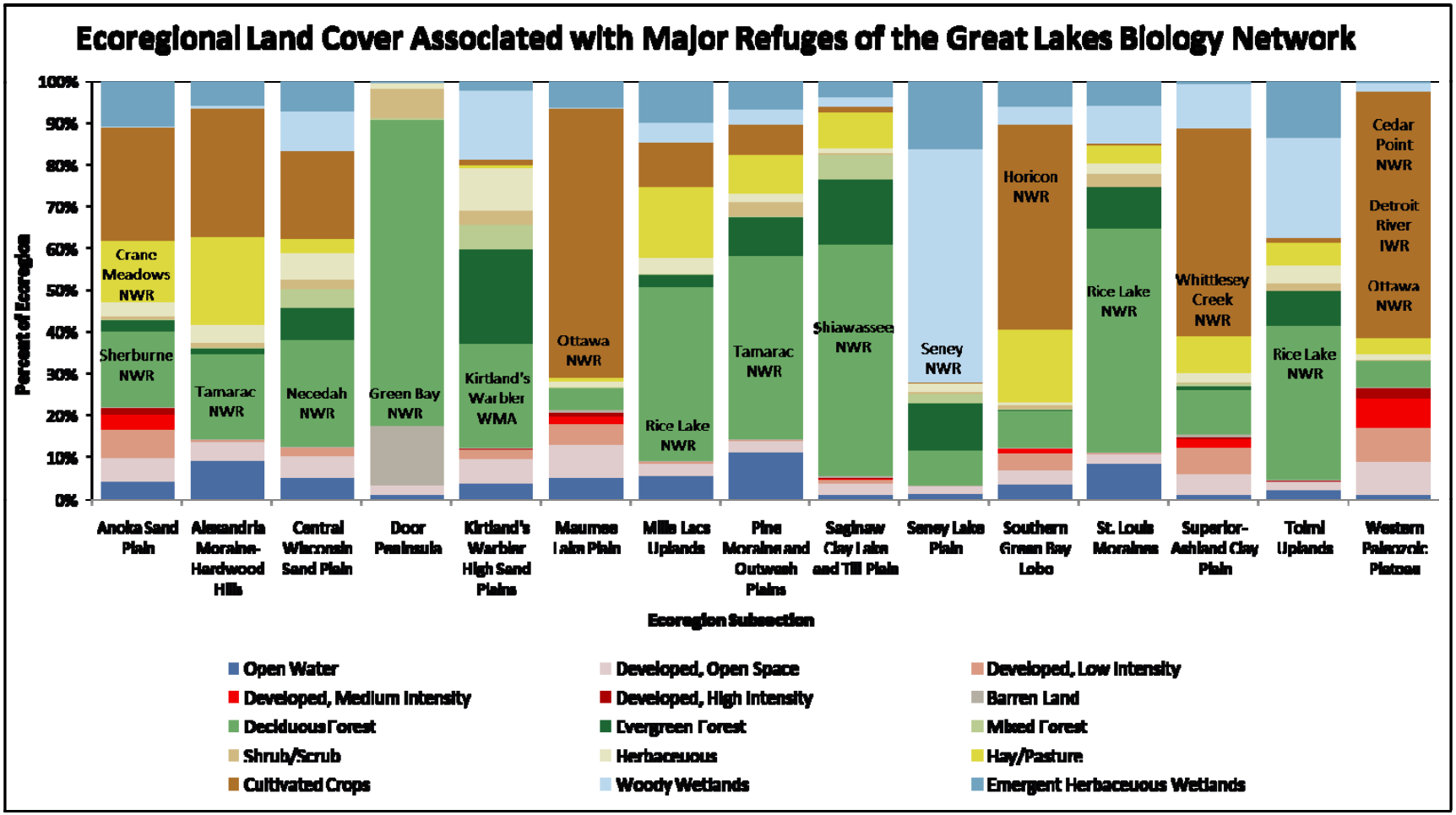


Fig. 5. Percentage of each refuge of the Great Lakes Biology Network in land covers comprising ≥10% of the refuge. Refuges are listed in alphabetical order.

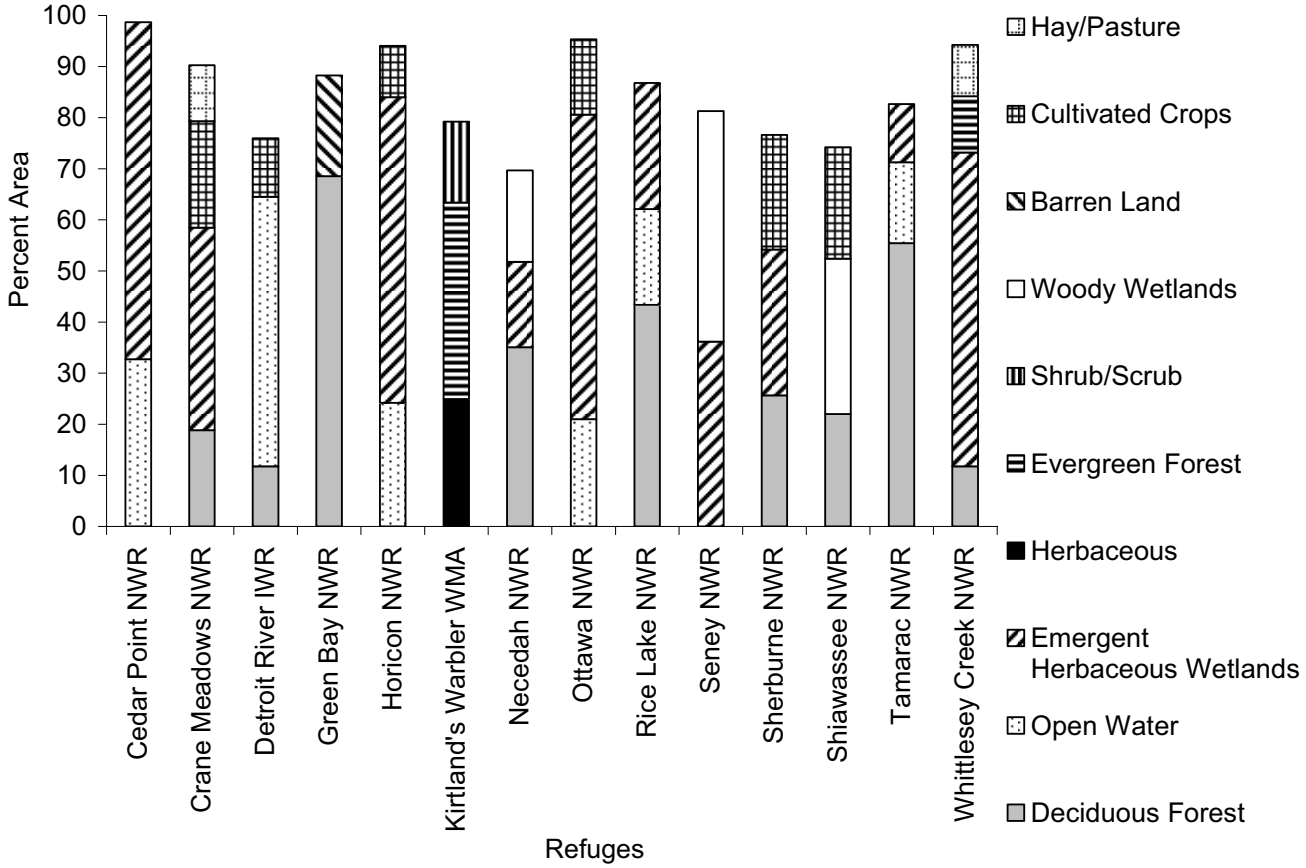


Fig. 6. Landscape shape index for each ecoregion and refuge of the Great Lakes Biology Network. Because it contains significantly less area than the other ecoregions, data for the Door Peninsula were excluded.

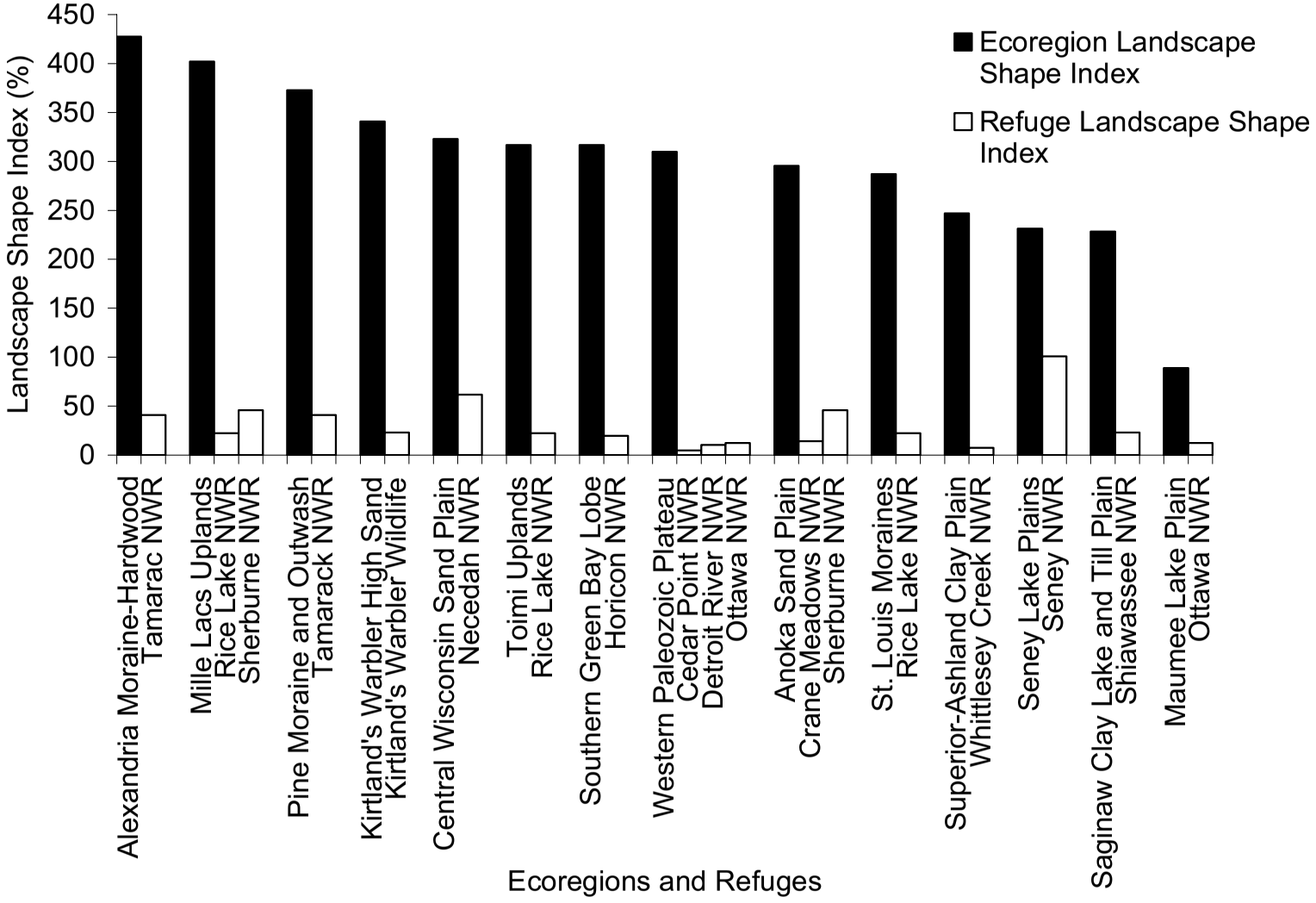


Fig. 7. Relationship between landscape shape index for each ecoregion and its associated refuge of the Great Lakes Biology Network. Refuge codes used are those shown in Fig. 2 and Table 2, above. Data are not shown for ecoregions with <35% area of a refuge.

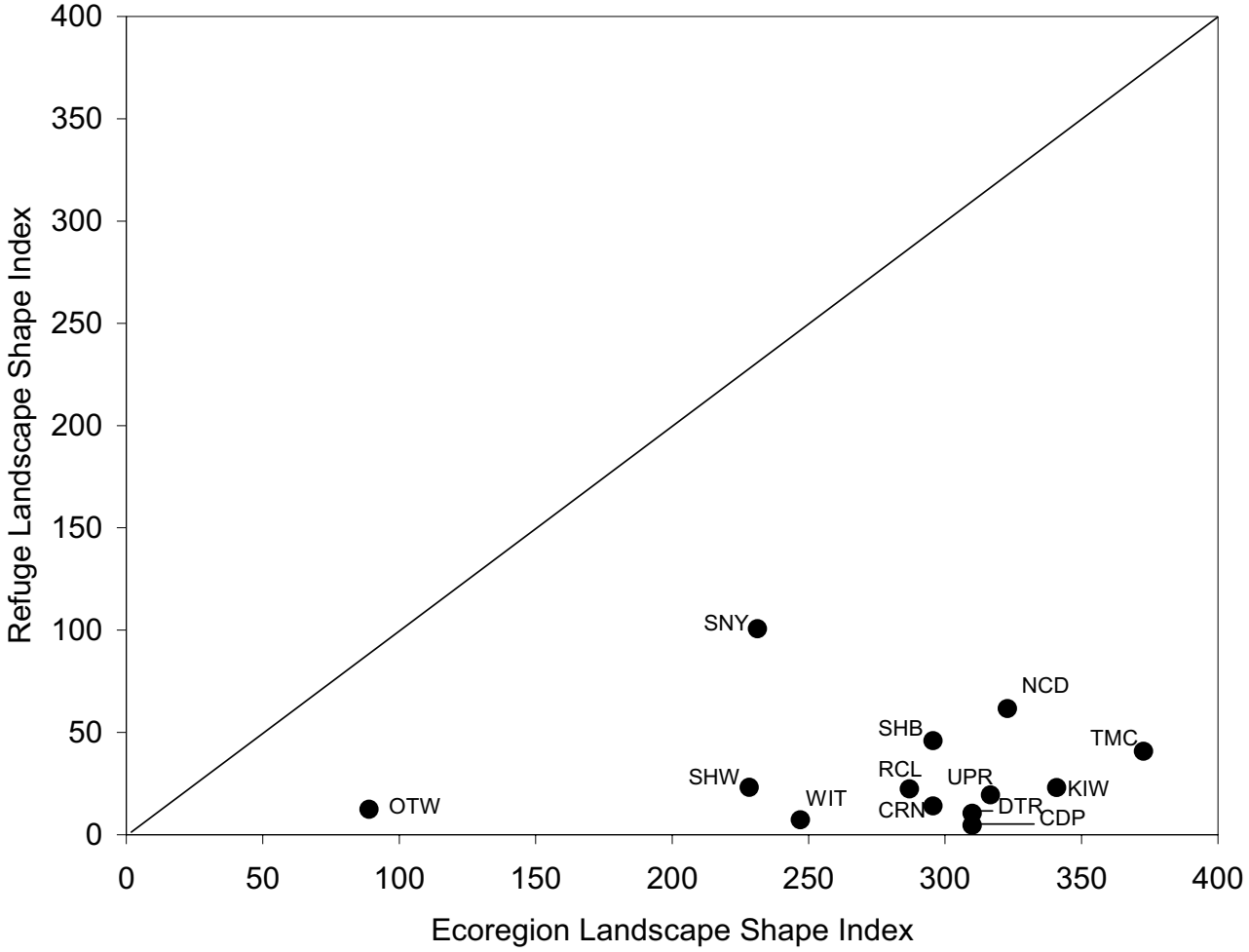


Fig. 8. Mean patch area for each ecoregion and its associated refuge of the Great Lakes Biology Network. Because it contains significantly less area than the other ecoregions, data for the Door Peninsula were excluded.

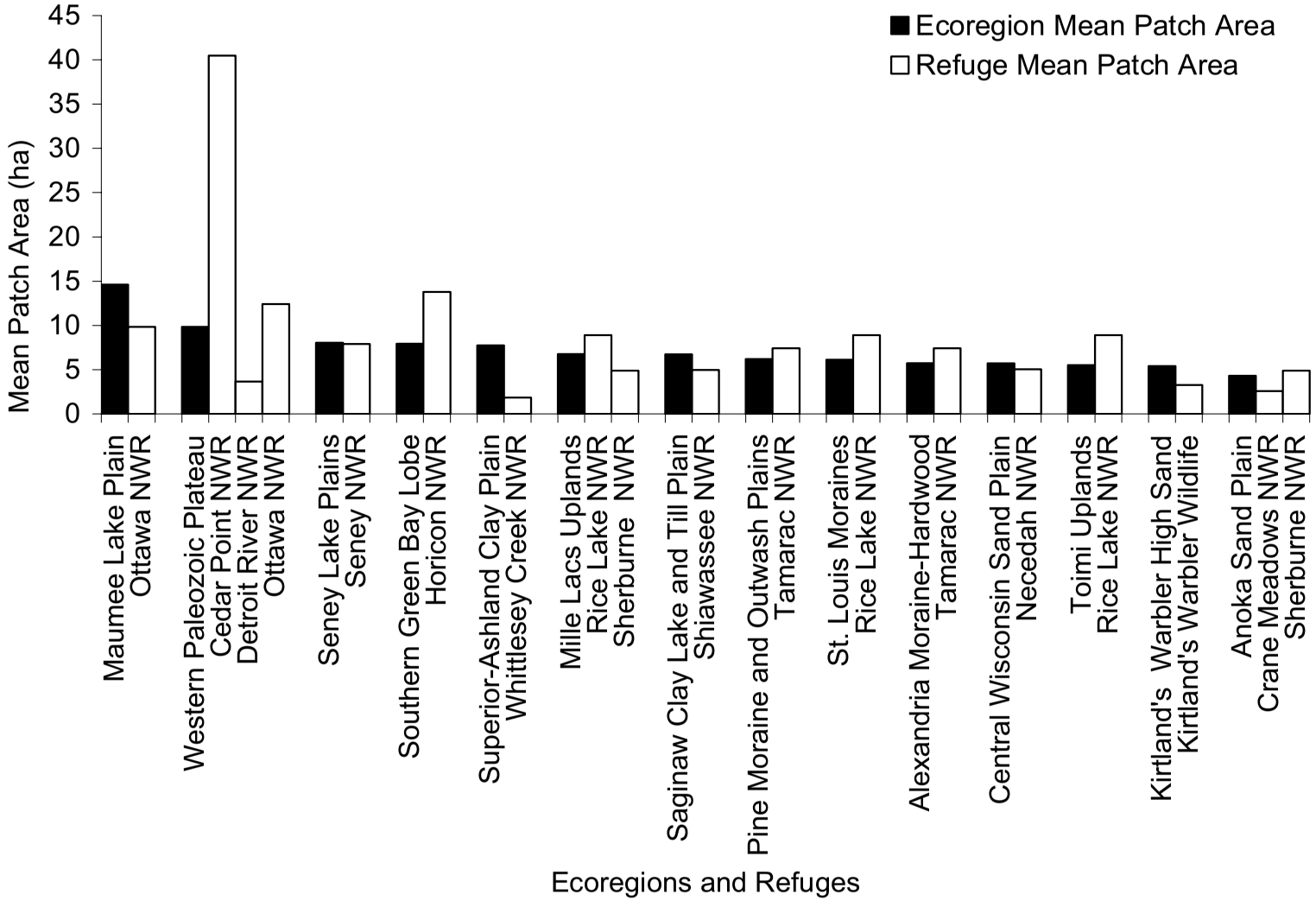


Fig. 9. Relationship between mean patch area for each ecoregion and its associated refuge of the Great Lakes Biology Network. Refuge codes used are those shown in Fig. 2 and Table 2, above. Data are not shown for ecoregions with <35% area of a refuge. Data for Cedar Point NWR and its associated ecoregion were an extreme outlier.

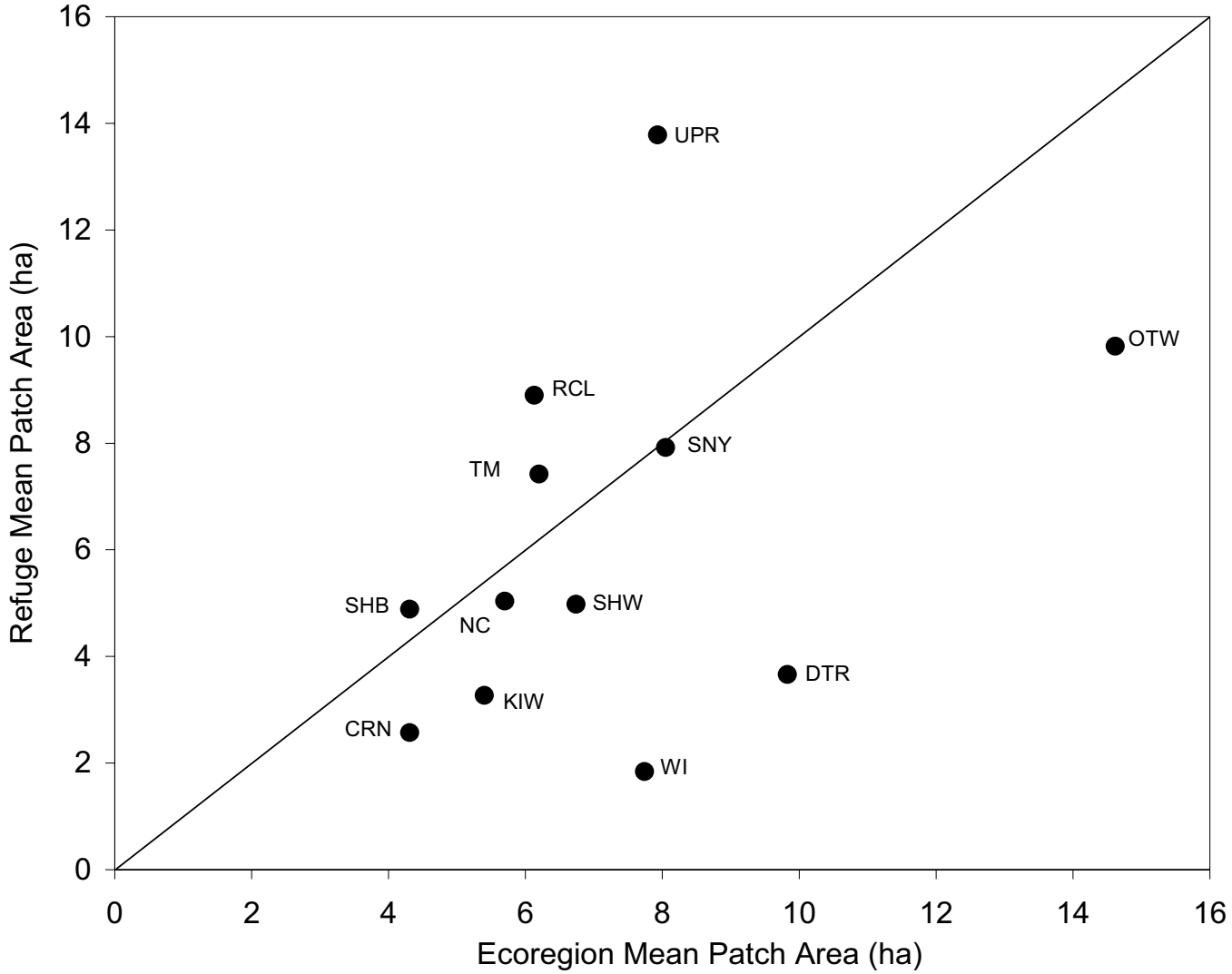


Fig. 10. Patch density for each ecoregion and its associated refuge of the Great Lakes Biology Network. Because it contains significantly less area than the other ecoregions, data for the Door Peninsula were excluded.

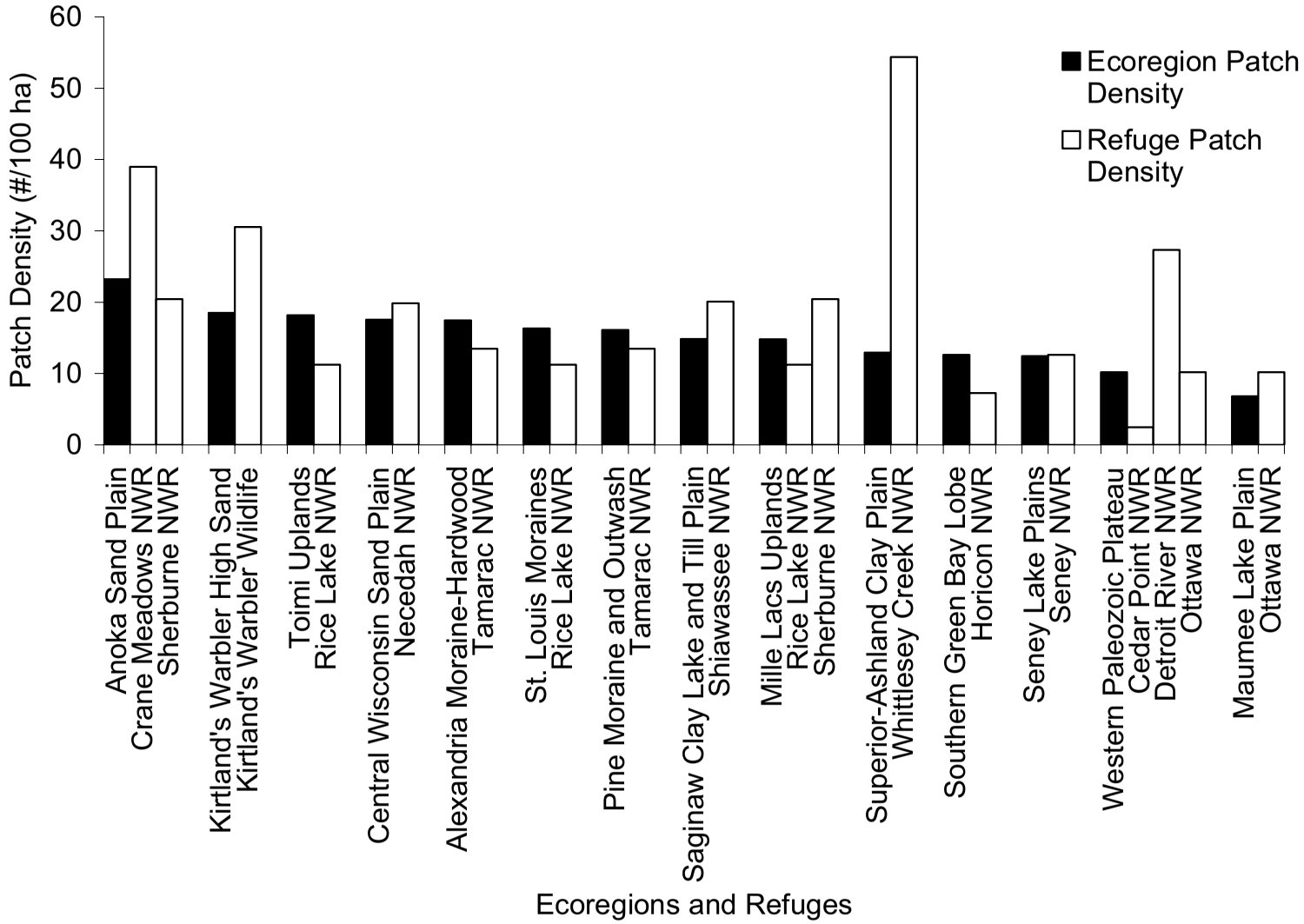
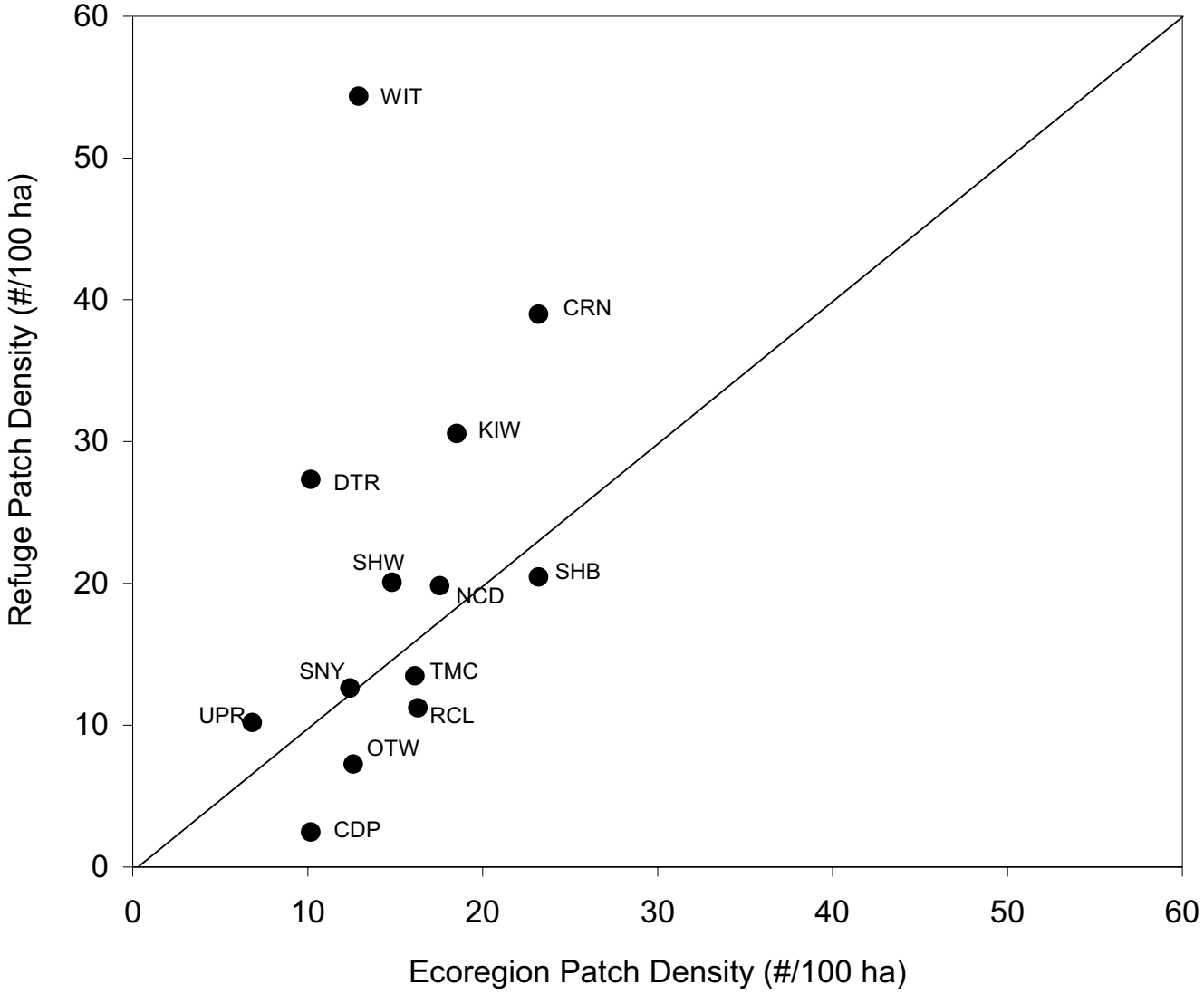


Fig. 11. Relationship between patch density for each ecoregion and its associated refuge of the Great Lakes Biology Network. Refuge codes used are those shown in Fig. 2 and Table 2, above. Data are not shown for ecoregions with <35% area of a refuge.



Appendix 1. National Land Cover Data (NLCD 2001) land class definitions for 15 land covers found within ecoregions of the Great Lakes Biology Network. The number in front of each land cover refers to its GIS code.

11. Open Water - All areas of open water, generally with <25 percent cover of vegetation or soil.

21. Developed, Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for <20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes

22. Developed, Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

23. Developed, Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

24. Developed, High Intensity - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80-100 percent of the total cover.

31. Barren Land (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for <15 percent of total cover.

41. Deciduous Forest - Areas dominated by trees generally >5 meters tall, and >20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest - Areas dominated by trees generally >5 meters tall, and >20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest - Areas dominated by trees generally >5 meters tall, and >20 percent of total vegetation cover. Neither deciduous nor evergreen species are >75 percent of total tree cover.

52. Shrub/Scrub - Areas dominated by shrubs; <5 meters tall with shrub canopy typically >20 percent of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

71. Grassland/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally >80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for >20 percent of total vegetation.

82. Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for >20 percent of total vegetation. This class also includes all land being actively tilled.

90. Woody Wetlands - Areas where forest or shrubland vegetation accounts for >20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

95. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for >80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Appendix 2. Ownership (multiple sources) by ecoregion, listed in ranked order by area. Ecoregions are listed alphabetically.

Table 1. Alexandria Moraine-Hardwood Hills

Ownership	Acres	Percent
Private	3,324,413.04	95.07
State	93,990.40	2.69
Federal	56,015.10	1.60
Private Non-Industrial	8,283.90	0.24
Private Industrial	7,914.58	0.23
Tribal	2,959.71	0.08
County	2,253.43	0.06
Private Conservancy	560.79	0.02
Other Public	235.36	0.01
Total	**3,496,626.31**	**100.00**

Table 2. Anoka Sand Plain

Ownership	Acres	Percent
Private	1,064,825.78	88.72
State	57,611.15	4.80
Federal	43,207.67	3.60
County	12,700.43	1.06
Private Industrial	10,855.10	0.90
Other Public	8,279.82	0.69
Private Non-Industrial	2,235.14	0.19
Private Conservancy	496.21	0.04
Total	**1,200,211.31**	**100.00**

Table 3. Central Wisconsin Sand Plain

Ownership	Acres	Percent
No Data	1,281,091.84	79.23
Federal	196,587.34	12.16
County	93,489.00	5.78
Local	42,647.97	2.64
Private	3,181.02	0.20
Total	**1,616,997.17**	**100.00**

Table 4. Kirtland's Warbler High Sand Plain

Ownership	Acres	Percent
No Data	758,605.26	40.31
State	733,502.14	38.98
Federal	333,957.28	17.75
Private	49,614.45	2.64
Local	3,969.71	0.21
NGO	1,318.15	0.07
County	743.01	0.04
Total	**1,881,710.00**	**100.00**

Table 5. Maumee Lake Plain

Ownership	Acres	Percent
No Data	429,969.72	93.84
Private	11,893.43	2.60
State	10,689.97	2.33
Federal	3,952.22	0.86
County	1,213.48	0.26
Local	360.37	0.08
NGO	121.34	0.03
Total	**458,200.53**	**100.00**

Table 6. Mille Lacs Uplands

Ownership GAP	Ownership CARL	Acres	Percent
Private		2,746,207.45	71.61
State		595,641.93	15.53
	No Data	384,380.14	10.02
	Federal	27,093.37	0.71
Private Industrial		23,626.26	0.62
Private Non-Industrial		20,927.35	0.55
	County	17,322.42	0.45
Federal		5,277.83	0.14
Tribal		5,241.51	0.14
County		4,399.13	0.11
Other Public		3,464.89	0.09
Private Conservancy		658.84	0.02
	State	310.61	0.01
	Private	170.01	0.00
Total		**3,834,721.74**	**100.00**

Table 7. Pine Moraine and Outwash Plains

Ownership	Acres	Percent
Private	1,985,554.29	65.62
State	761,422.24	25.16
Federal	158,797.10	5.25
Private Industrial	94,192.39	3.11
Tribal	10,107.58	0.33
Other Public	6,550.31	0.22
Private Non-Industrial	5,895.38	0.19
Private Conservancy	2,133.05	0.07
County	1,097.90	0.04
Total	**3,025,750.25**	**100.00**

Table 8. Saginaw Clay Lake and Till Plains

Ownership	Acres	Percent
No Data	1,219,103.83	92.93
State	53,461.11	4.08
Federal	17,670.01	1.35
Private	15,603.05	1.19
Local	3,831.16	0.29
County	1,819.19	0.14
NGO	305.80	0.02
Total	**1,311,794.15**	**100.00**

Table 9. Seney Lake Plain

Ownership	Acres	Percent
Federal	375,462.82	42.46
State	330,670.61	37.40
No Data	171,809.33	19.43
Local	5,500.66	0.62
Private	656.18	0.07
NGO	146.12	0.02
Total	**884,245.72**	**100.00**

Table 10. Southern Green Bay Lobe

Ownership	Acres	Percent
No Data	2,620,619.47	94.15
Federal	153,489.61	5.51
County	6,346.05	0.23
Private	2,355.48	0.08
State	501.73	0.02
Total	**2,783,312.34**	**100.00**

Table 11. St. Louis Moraines

Ownership	Acres	Percent
Private	727,108.78	44.09
State	576,929.63	34.98
Private Industrial	170,831.80	10.36
Federal	161,164.53	9.77
County	7,138.00	0.43
Other Public	4,570.04	0.28
Private Non-Industrial	802.22	0.05
Tribal	541.72	0.03
Total	**1,649,086.72**	**100.00**

Table 12. Superior-Ashland Clay Plain

Ownership GAP	Ownership CARL	Acres	Percent
	No Data	852,928.81	65.43
	Federal	203,200.67	15.59
	County	90,816.73	6.97
Private		70,160.01	5.38
	State	43,258.83	3.32
State		32,088.85	2.46
Private Industrial		6,702.30	0.51
County		1,944.25	0.15
	Private	1,224.98	0.09
	Local	490.40	0.04
	Unknown	418.63	0.03
Private Non-Industrial		210.19	0.02
Other Public		162.37	0.01
	NGO	40.07	< 0.01
Total		**1,303,647.08**	**100.00**

Table 13. Toimi Uplands

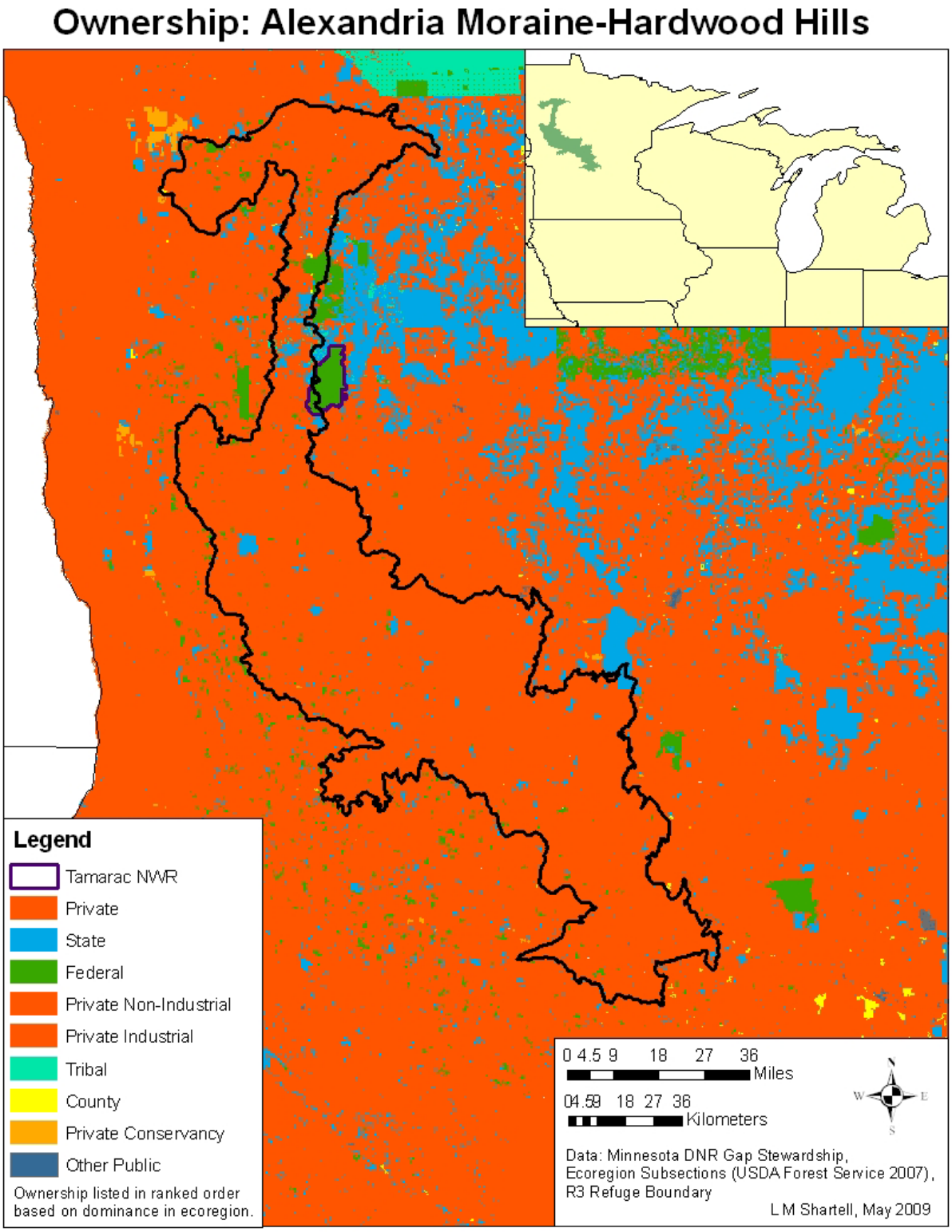
Ownership	Acres	Percent
State	769,356.09	50.79
Private	633,049.14	41.79
Private Industrial	79,546.27	5.25
Federal	11,432.70	0.75
County	10,687.92	0.71
Private Non-Industrial	5,900.75	0.39
Other Public	2,611.03	0.17
Private Conservancy	2,105.22	0.14
Tribal	225.56	0.01
Total	**1,514,914.69**	**100.00**

Table 14. Western Paleozoic Plateau

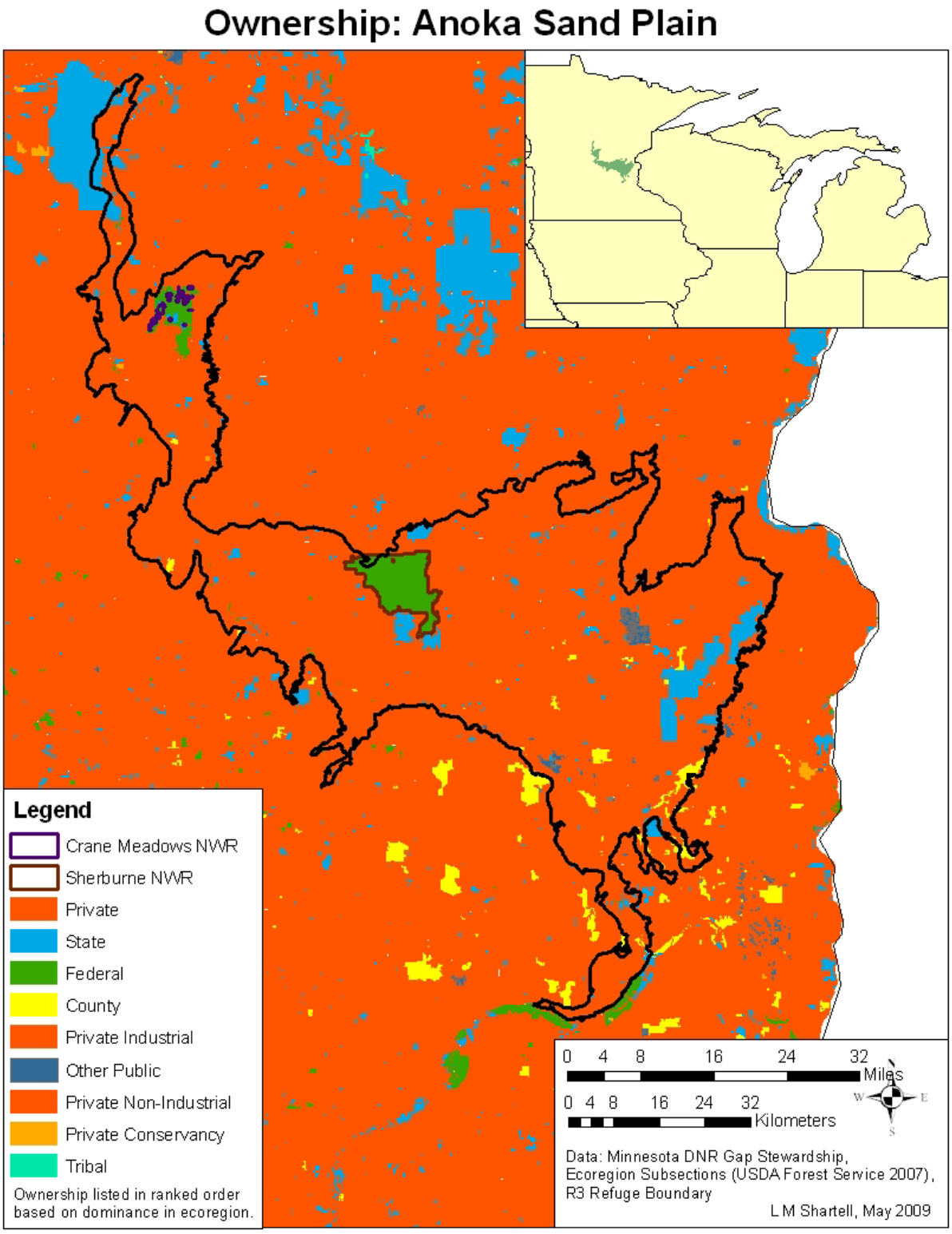
Ownership	Acres	Percent
No Data	3,405,603.70	97.22
Local	36,817.34	1.05
Private	22,788.09	0.65
State	20,263.58	0.58
County	9,002.65	0.26
Federal	5,189.57	0.15
NGO	2,734.22	0.08
Unknown	639.26	0.02
Total	**3,503,038.41**	**100.00**

Appendix 3. Maps of ownership (multiple sources) by ecoregion. Ecoregions are listed alphabetically.

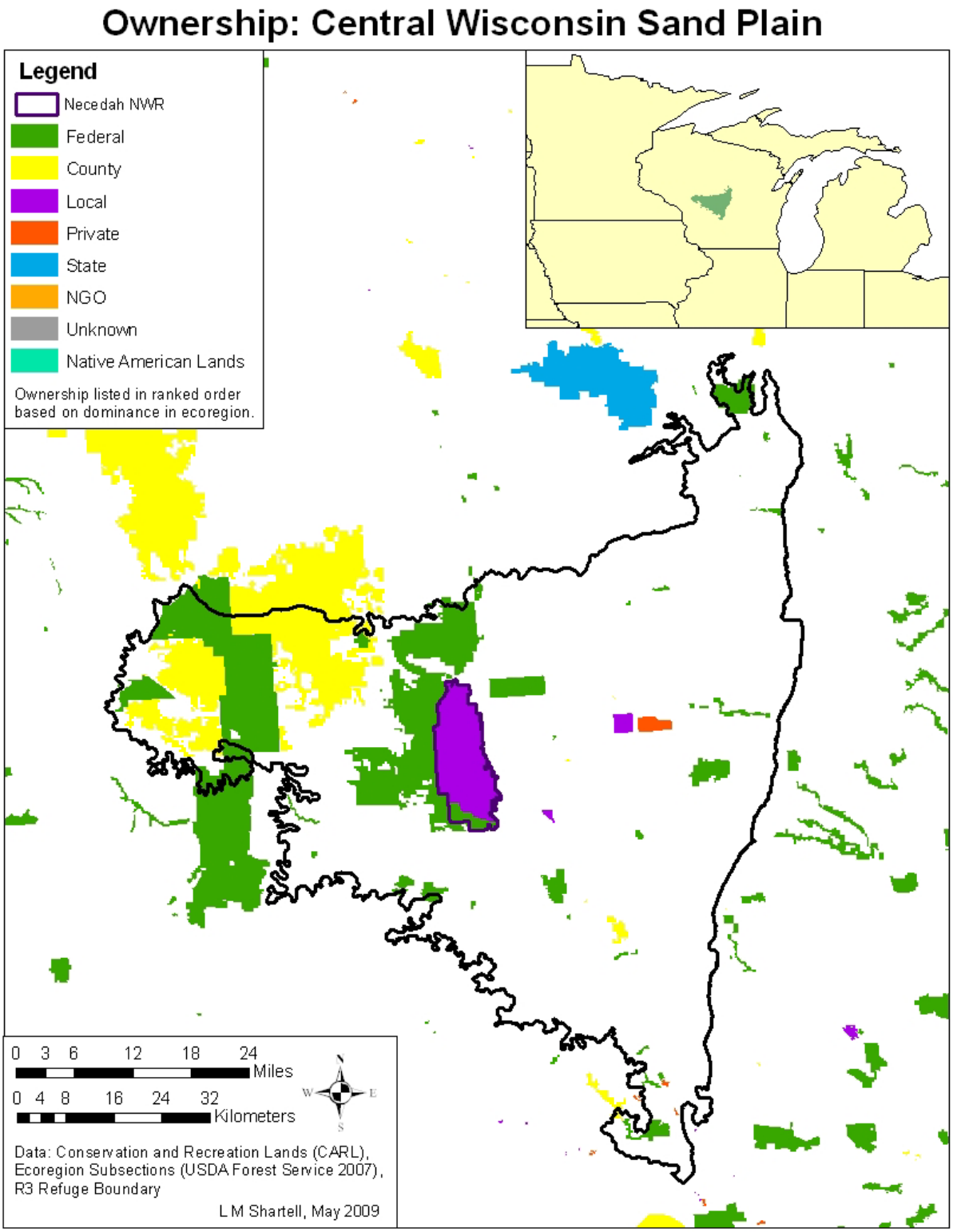
Map 1.



Map 2.

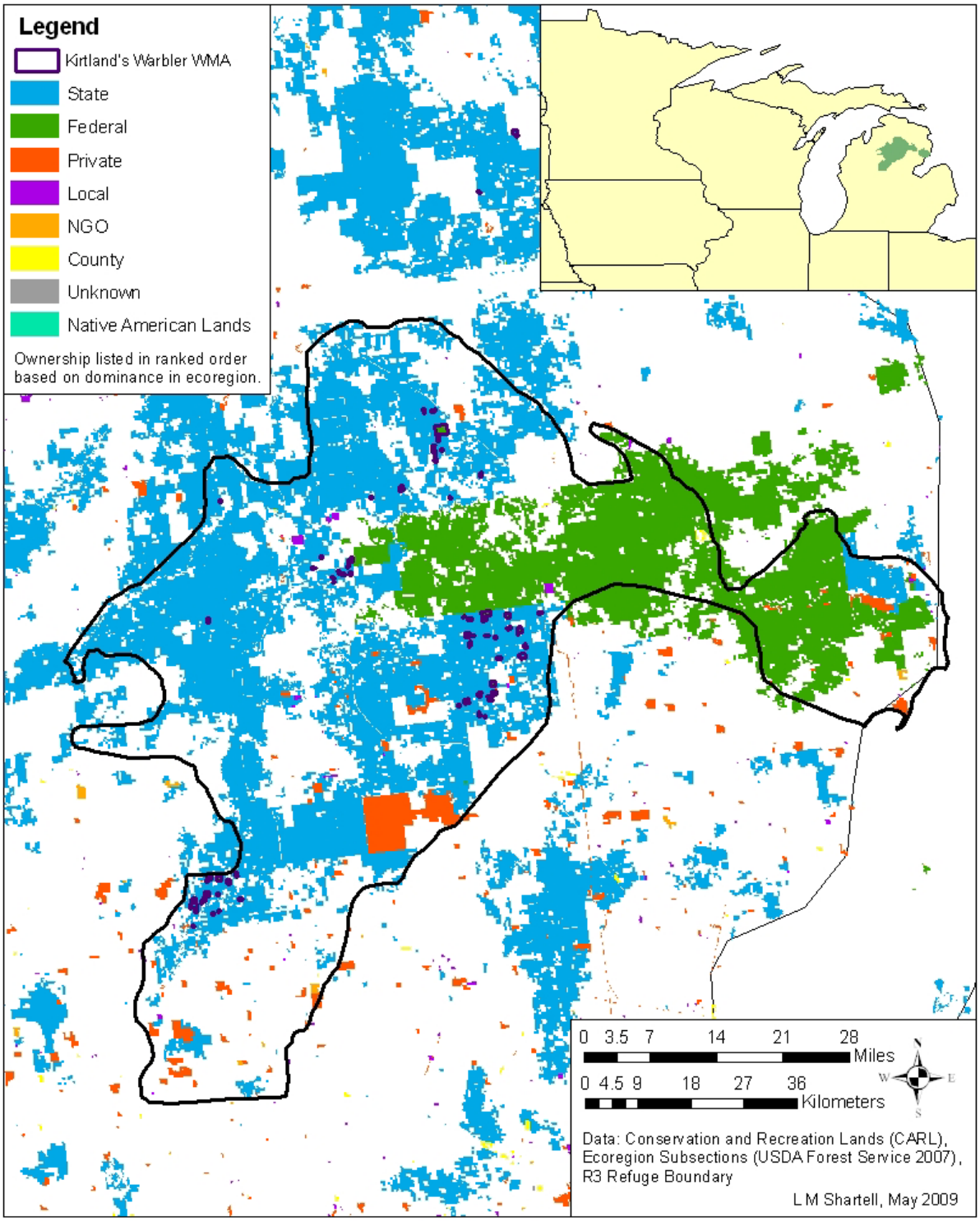

Ownership: Anoka Sand Plain
Legend
Crane Meadows NWR
Sherburne NWR
Private
State
Federal
County
Private Industrial
Other Public
Private Non-Industrial
Private Conservancy
Tribal
Ownership listed in ranked order based on dominance in ecoregion.
0 4 8 16 24 32
Miles
0 4 8 16 24 32
Kilometers
N
W
E
S
Data: Minnesota DNR Gap Stewardship, Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 3.

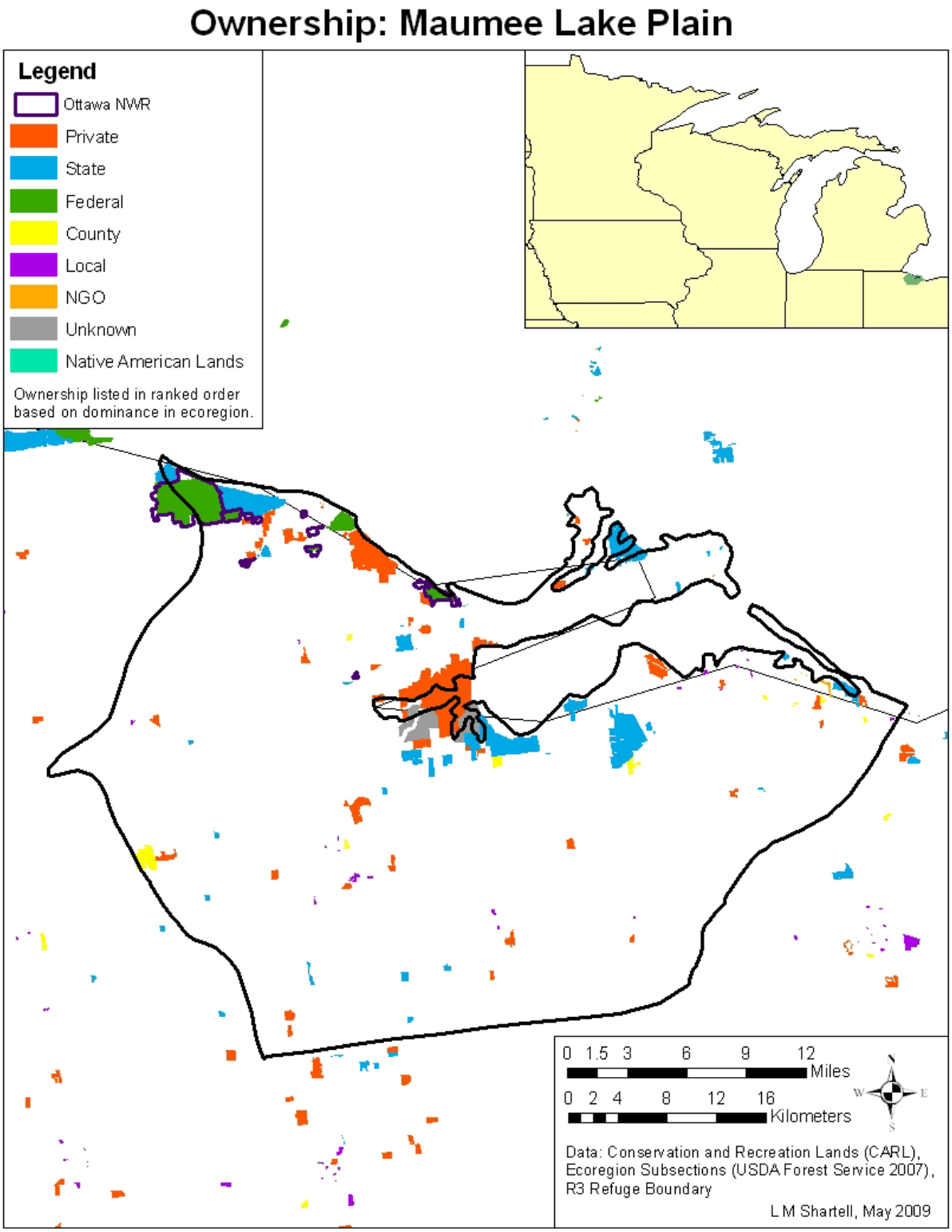

Ownership: Central Wisconsin Sand Plain
Legend
Necedah NWR
Federal
County
Local
Private
State
NGO
Unknown
Native American Lands
Ownership listed in ranked order based on dominance in ecoregion.
0 3 6 12 18 24
Miles
0 4 8 16 24 32
Kilometers
W
E
S
Data: Conservation and Recreation Lands (CARL), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 4.

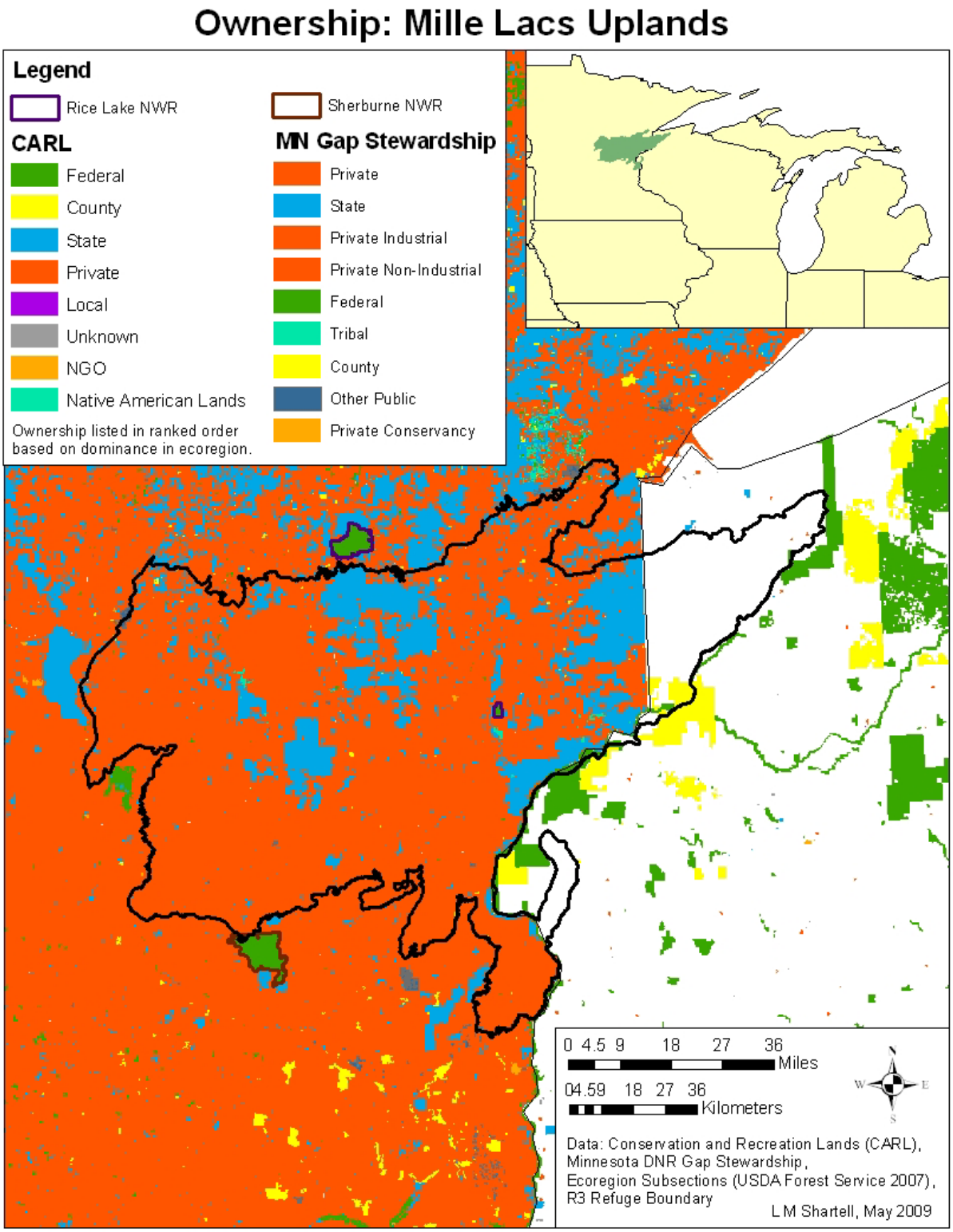
Ownership: Kirtland's Warbler High Sand Plain



Map 5.

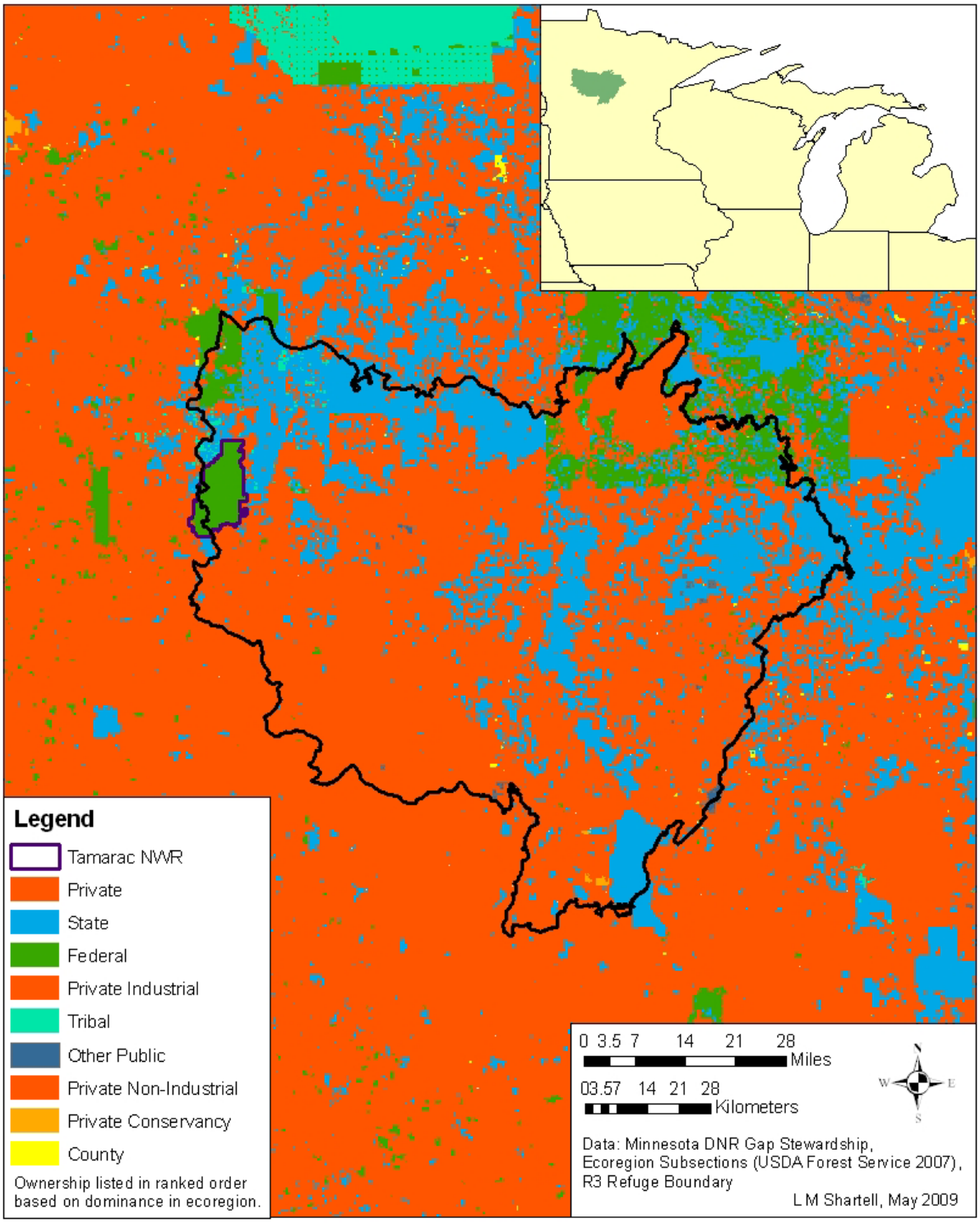

Ownership: Maumee Lake Plain
Legend
Ottawa NWR
Private
State
Federal
County
Local
NGO
Unknown
Native American Lands
Ownership listed in ranked order based on dominance in ecoregion.
0 1.5 3 6 9 12
Miles
0 2 4 8 12 16
Kilometers
Data: Conservation and Recreation Lands (CARL), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 6.


Ownership: Mille Lacs Uplands
Legend
Rice Lake NWR
Sherburne NWR
CARL
Federal
County
State
Private
Local
Unknown
NGO
Native American Lands
Ownership listed in ranked order based on dominance in ecoregion.
MN Gap Stewardship
Private
State
Private Industrial
Private Non-Industrial
Federal
Tribal
County
Other Public
Private Conservancy
0 4.5 9 18 27 36
Miles
04.59 18 27 36
Kilometers
Data: Conservation and Recreation Lands (CARL),
Minnesota DNR Gap Stewardship,
Ecoregion Subsections (USDA Forest Service 2007),
R3 Refuge Boundary
L M Shartell, May 2009

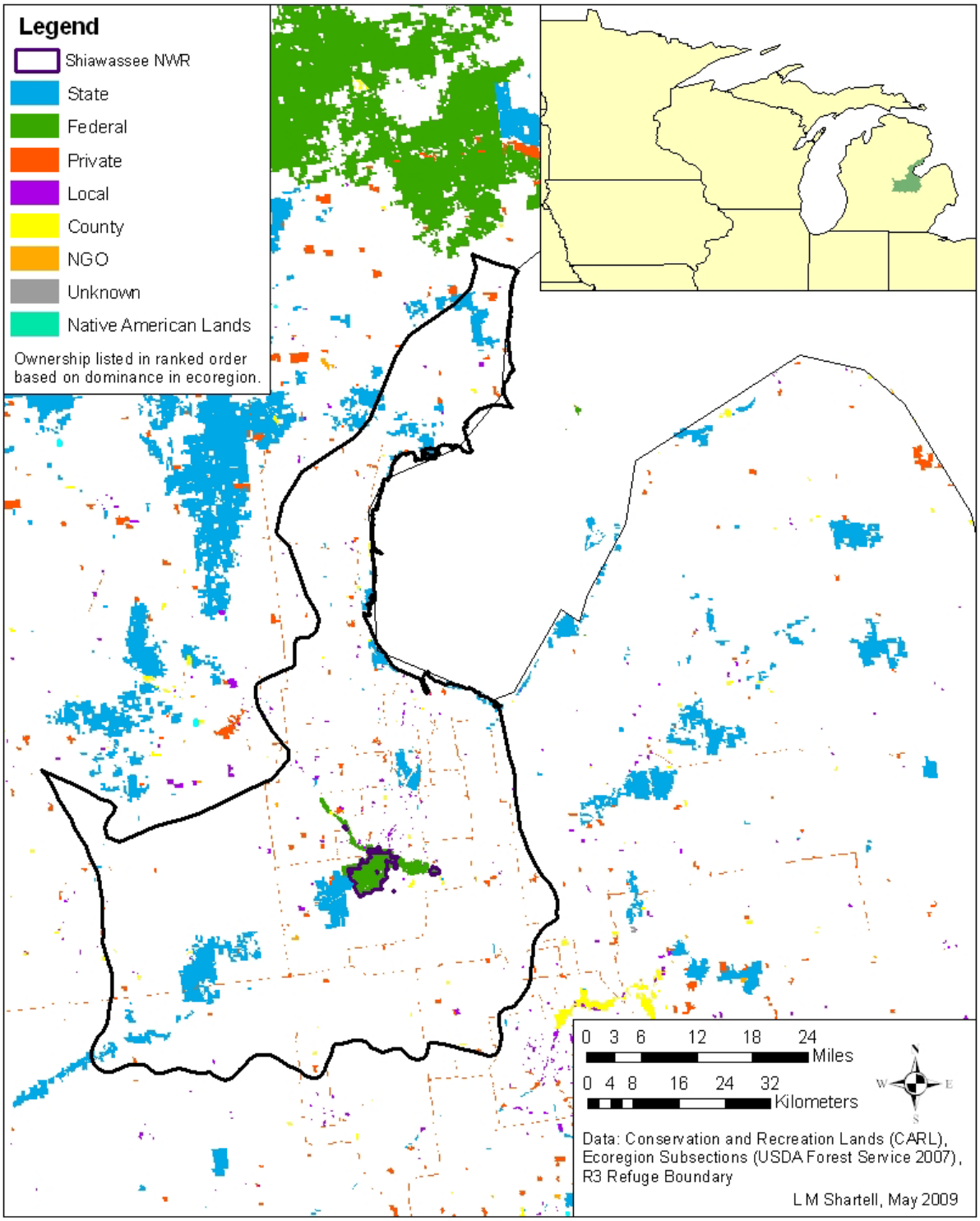
Map 7.

Ownership: Pine Moraine and Outwash Plains

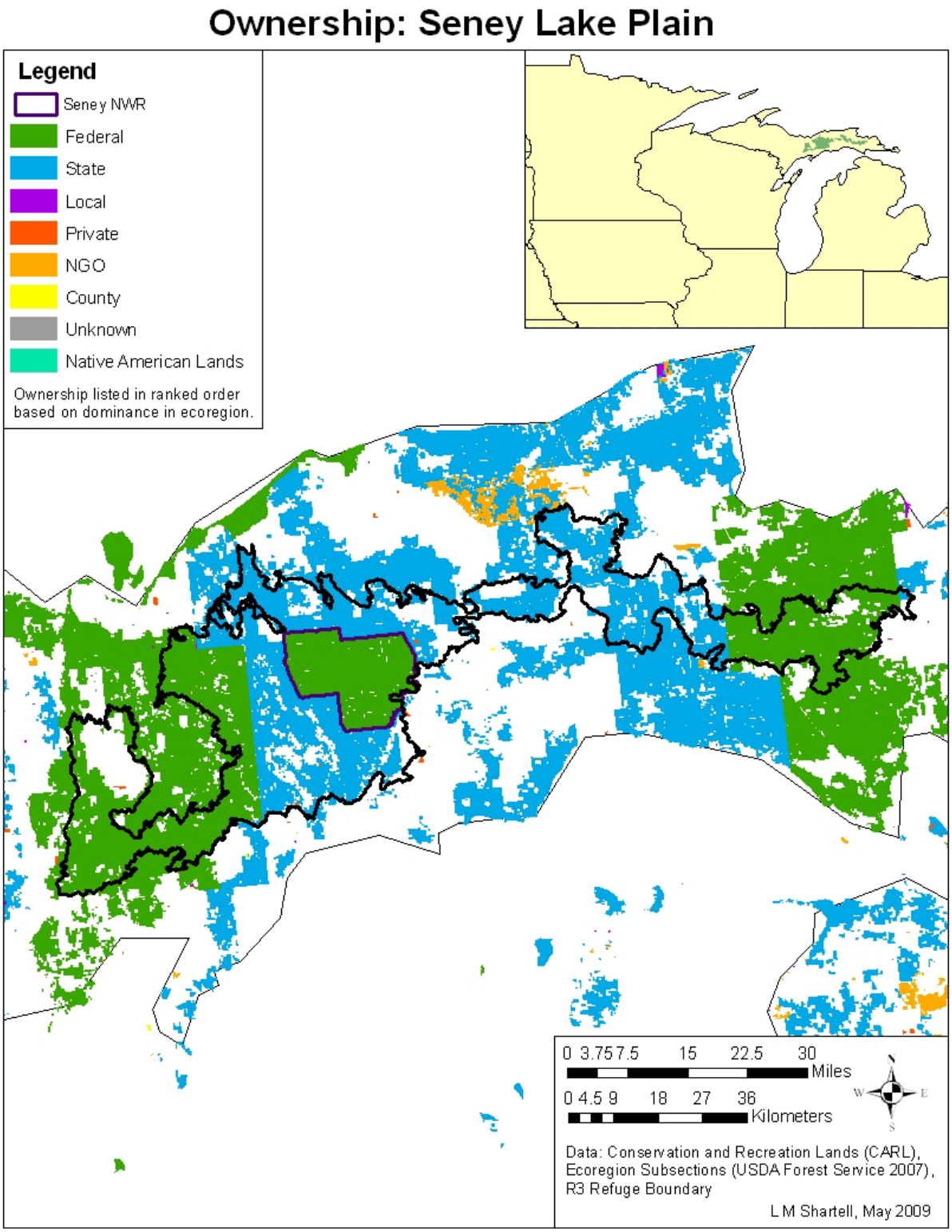


Map 8.

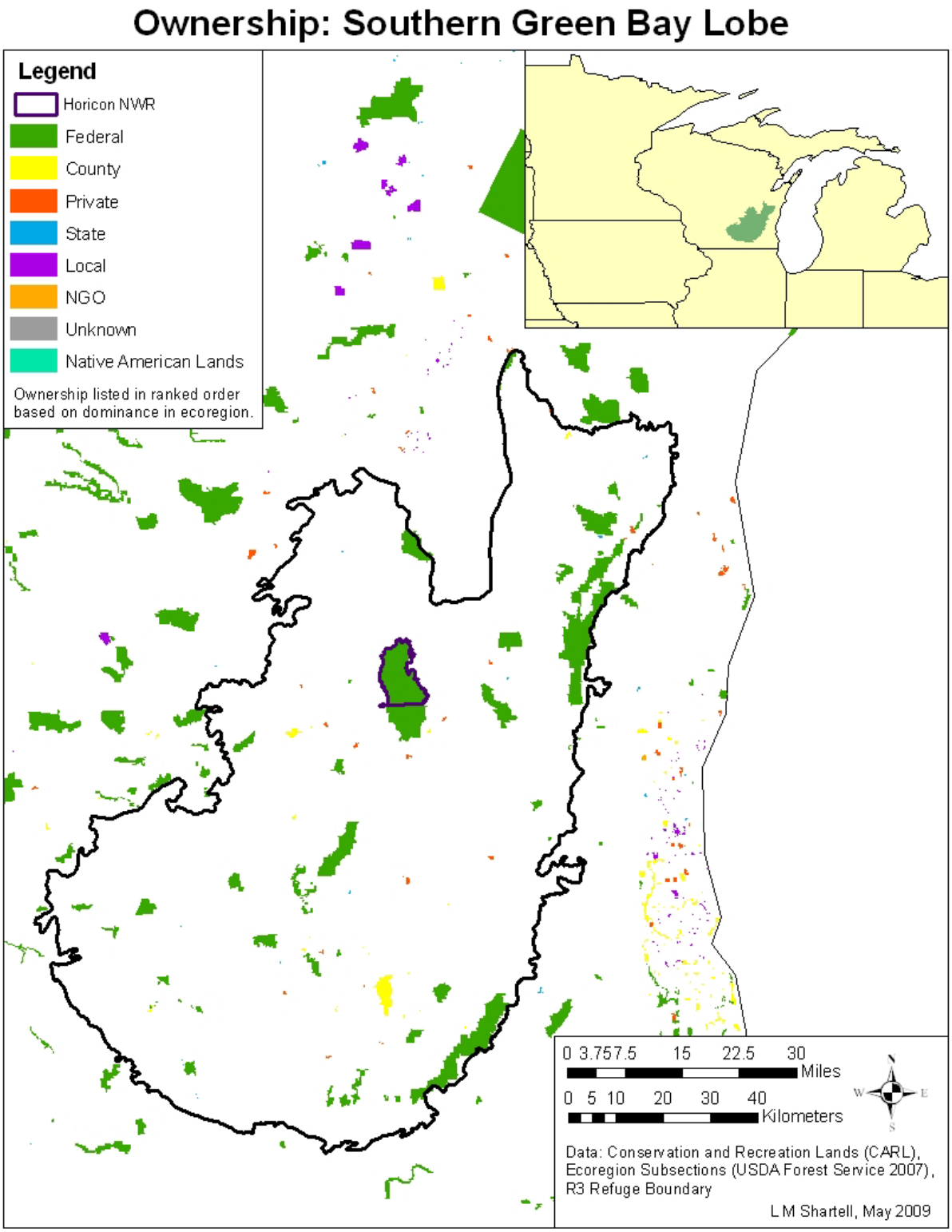
Ownership: Saginaw Clay Lake and Till Plain



Map 9.

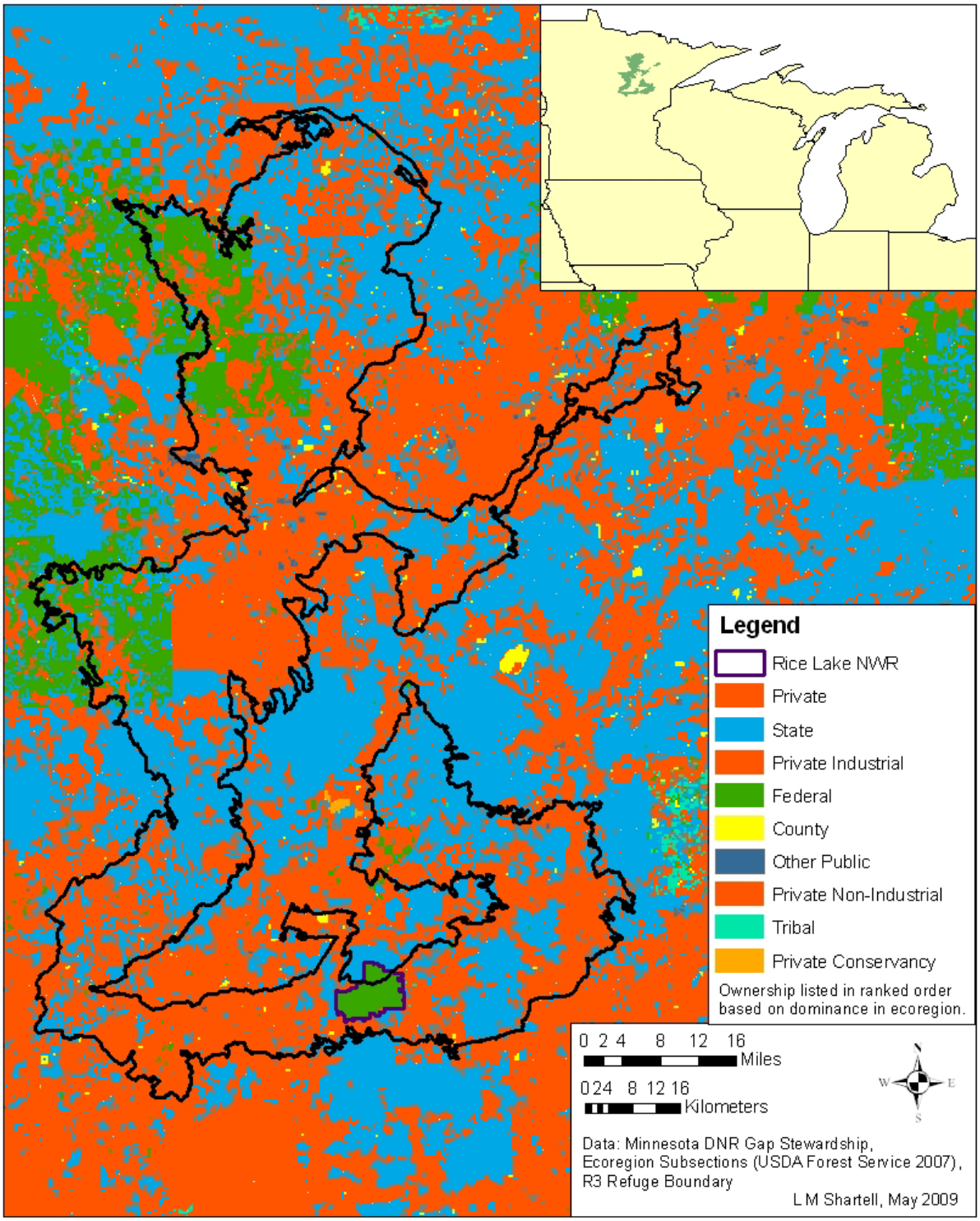

Ownership: Seney Lake Plain
Legend
Seney NWR
Federal
State
Local
Private
NGO
County
Unknown
Native American Lands
Ownership listed in ranked order based on dominance in ecoregion.
0 3.75 7.5 15 22.5 30
Miles
0 4.5 9 18 27 36
Kilometers
N
W
E
S
Data: Conservation and Recreation Lands (CARL), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 10.

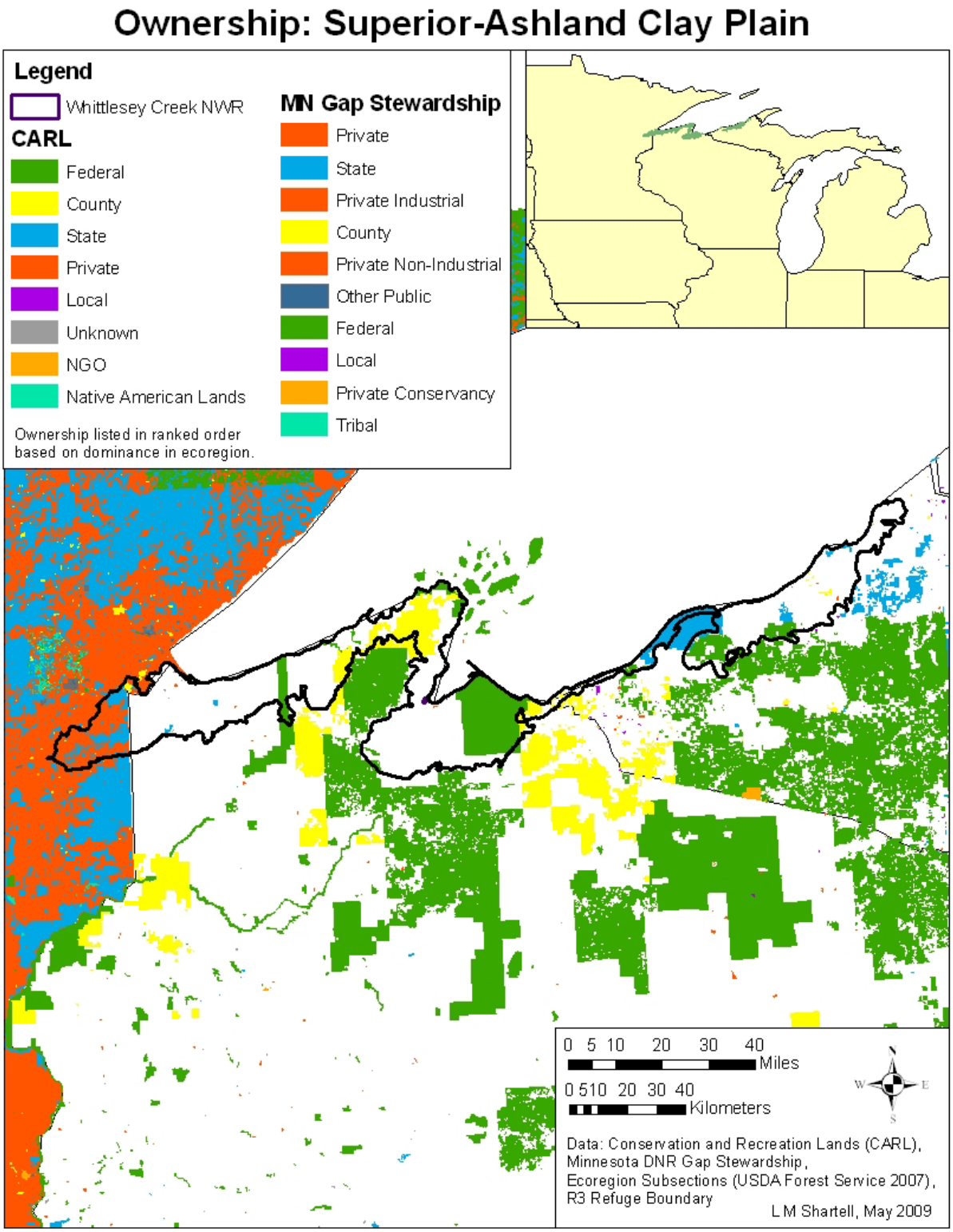

Ownership: Southern Green Bay Lobe
Legend
Horicon NWR
Federal
County
Private
State
Local
NGO
Unknown
Native American Lands
Ownership listed in ranked order based on dominance in ecoregion.
0 3.757.5 15 22.5 30
Miles
0 5 10 20 30 40
Kilometers
Data: Conservation and Recreation Lands (CARL), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 11.

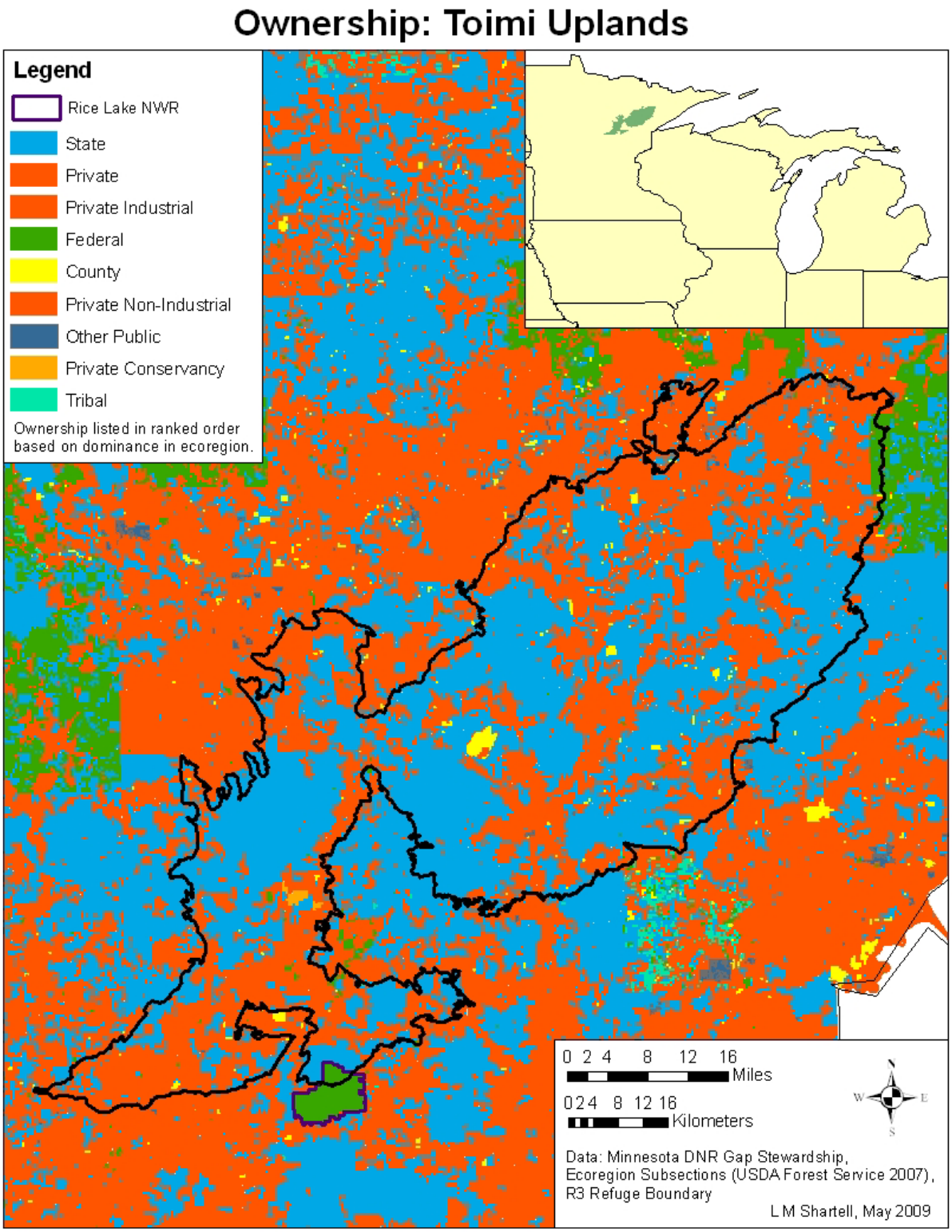
Ownership: St. Louis Moraines



Map 12.

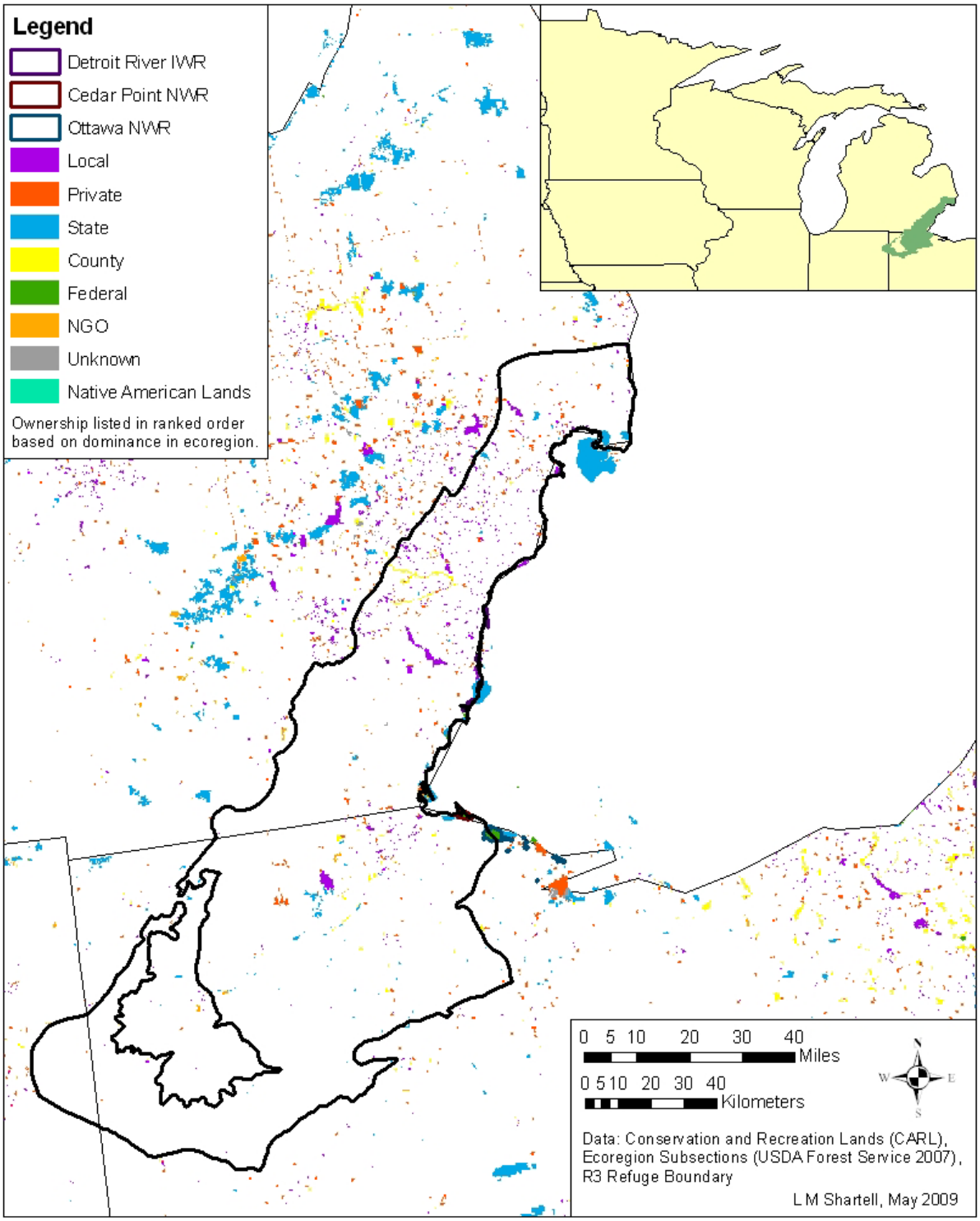

Ownership: Superior-Ashland Clay Plain
Legend
Whittlesey Creek NWR
CARL
Federal
County
State
Private
Local
Unknown
NGO
Native American Lands
Ownership listed in ranked order based on dominance in ecoregion.
MN Gap Stewardship
Private
State
Private Industrial
County
Private Non-Industrial
Other Public
Federal
Local
Private Conservancy
Tribal
0 5 10 20 30 40
Miles
0 510 20 30 40
Kilometers
Data: Conservation and Recreation Lands (CARL),
Minnesota DNR Gap Stewardship,
Ecoregion Subsections (USDA Forest Service 2007),
R3 Refuge Boundary
L M Shartell, May 2009

Map 13.


Ownership: Toimi Uplands
Legend
Rice Lake NWR
State
Private
Private Industrial
Federal
County
Private Non-Industrial
Other Public
Private Conservancy
Tribal
Ownership listed in ranked order based on dominance in ecoregion.
0 2 4 8 12 16
Miles
0 2 4 8 12 16
Kilometers
N
W
E
S
Data: Minnesota DNR Gap Stewardship, Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 14.

Ownership: Western Paleozoic Plateau



Appendix 4. Land cover (NLCD 2001) by ecoregion, listed in ranked order by area. Ecoregions are listed alphabetically.

Table 1. Alexandria Moraine-Hardwood Hills

Land cover	Acres	Percent
Cultivated Crops	1,072,628.11	30.68
Hay/Pasture	736,687.11	21.07
Deciduous Forest	708,332.17	20.26
Open Water	317,766.05	9.09
Emergent Herbaceous Wetlands	210,393.23	6.02
Herbaceous	159,493.31	4.56
Developed, Open Space	154,218.41	4.41
Evergreen Forest	50,647.64	1.45
Shrub/Scrub	35,198.55	1.01
Woody Wetlands	22,026.69	0.63
Developed, Low Intensity	20,754.71	0.59
Developed, Medium Intensity	3,448.20	0.10
Mixed Forest	2,468.90	0.07
Developed, High Intensity	1,726.64	0.05
Barren Land	835.97	0.02
Total	**3,496,625.69**	**100.00**

Table 2. Anoka Sand Plain

Land cover	Acres	Percent
Cultivated Crops	326,714.05	27.21
Deciduous Forest	217,114.92	18.08
Hay/Pasture	174,098.08	14.50
Emergent Herbaceous Wetlands	130,550.09	10.87
Developed, Low Intensity	82,150.03	6.84
Developed, Open Space	70,609.37	5.88
Open Water	46,157.65	3.84
Herbaceous	42,429.38	3.53
Developed, Medium Intensity	40,972.18	3.41
Evergreen Forest	35,289.57	2.94
Developed, High Intensity	22,012.89	1.83
Shrub/Scrub	6,833.41	0.57
Woody Wetlands	4,505.67	0.38
Mixed Forest	1,227.67	0.10
Barren Land	187.74	0.02
Total	**1,200,852.70**	**100.00**

Table 3. Central Wisconsin Sand Plain

Land cover	Acres	Percent
Deciduous Forest	411,687.89	25.46
Cultivated Crops	346,748.55	21.44
Woody Wetlands	152,330.27	9.42
Evergreen Forest	124,906.81	7.72
Emergent Herbaceous Wetlands	116,753.27	7.22
Herbaceous	104,630.57	6.47
Developed, Open Space	85,170.96	5.27
Open Water	78,110.70	4.83
Mixed Forest	73,700.46	4.56
Hay/Pasture	48,815.08	3.02
Shrub/Scrub	35,306.78	2.18
Developed, Low Intensity	29,478.91	1.82
Developed, Medium Intensity	6,186.37	0.38
Developed, High Intensity	2,674.26	0.17
Barren Land	495.54	0.03
Total	**1,616,996.43**	**100.00**

Table 4. Door Peninsula

Land cover	Acres	Percent
Deciduous Forest	220.28	73.25
Barren Land	43.08	14.32
Shrub/Scrub	21.37	7.11
Developed, Open Space	6.13	2.04
Herbaceous	4.61	1.53
Open Water	2.81	0.93
Emergent Herbaceous Wetlands	1.33	0.44
Mixed Forest	1.11	0.37
Total	**300.73**	**100.00**

Table 5. Kirtland's Warbler High Sand Plains

Land cover	Acres	Percent
Deciduous Forest	469,501.24	24.95
Evergreen Forest	427,260.89	22.71
Woody Wetlands	311,588.70	16.56
Herbaceous	195,909.65	10.41
Developed, Open Space	113,458.37	6.03
Mixed Forest	110,409.94	5.87
Open Water	65,317.90	3.47
Shrub/Scrub	62,214.62	3.31
Emergent Herbaceous Wetlands	43,799.99	2.33
Developed, Low Intensity	39,291.10	2.09
Cultivated Crops	22,894.17	1.22
Hay/Pasture	12,031.69	0.64
Developed, Medium Intensity	4,623.47	0.25
Barren Land	2,147.05	0.11
Developed, High Intensity	1,260.98	0.07
Total	**1,881,709.76**	**100.00**

Table 6. Maumee Lake Plain

Land cover	Acres	Percent
Cultivated Crops	296,592.65	64.73
Developed, Open Space	36,278.26	7.92
Emergent Herbaceous Wetlands	29,362.21	6.41
Deciduous Forest	25,187.02	5.50
Developed, Low Intensity	23,021.38	5.02
Open Water	22,648.98	4.94
Developed, Medium Intensity	7,919.33	1.73
Herbaceous	5,589.39	1.22
Developed, High Intensity	3,792.20	0.83
Hay/Pasture	3,641.43	0.79
Barren Land	3,364.81	0.73
Woody Wetlands	670.53	0.15
Evergreen Forest	123.63	0.03
Mixed Forest	8.31	< 0.01
Total	**458,200.12**	**100.00**

Table 7. Mille Lacs Uplands

Land cover	Acres	Percent
Deciduous Forest	1,591,823.74	41.51
Hay/Pasture	655,248.14	17.09
Cultivated Crops	409,170.47	10.67
Emergent Herbaceous Wetlands	387,093.30	10.09
Open Water	206,740.25	5.39
Woody Wetlands	180,303.38	4.70
Herbaceous	137,708.63	3.59
Developed, Open Space	112,751.24	2.94
Evergreen Forest	111,707.34	2.91
Developed, Low Intensity	21,659.24	0.56
Shrub/Scrub	11,490.77	0.30
Mixed Forest	3,746.68	0.10
Developed, Medium Intensity	3,673.05	0.10
Developed, High Intensity	1,326.99	0.03
Barren Land	284.02	0.01
Total	**3,834,727.24**	**100.00**

Table 8. Pine Moraine and Outwash Plains

Land cover	Acres	Percent
Deciduous Forest	1,331,852.25	44.01
Open Water	333,508.82	11.02
Evergreen Forest	282,318.98	9.33
Hay/Pasture	281,387.55	9.30
Cultivated Crops	220,880.95	7.30
Emergent Herbaceous Wetlands	210,928.37	6.97
Woody Wetlands	106,411.67	3.52
Shrub/Scrub	105,250.36	3.48
Developed, Open Space	79,958.47	2.64
Herbaceous	56,816.15	1.88
Developed, Low Intensity	10,999.58	0.36
Mixed Forest	3,317.05	0.11
Developed, Medium Intensity	1,491.67	0.05
Developed, High Intensity	776.14	0.03
Barren Land	676.86	0.02
Total	**3,026,574.88**	**100.00**

Table 9. Saginaw Clay Lake and Till Plain

Land cover	Acres	Percent
Cultivated Crops	654,153.00	49.87
Deciduous Forest	141,286.42	10.77
Woody Wetlands	139,245.88	10.61
Hay/Pasture	114,424.29	8.72
Developed, Low Intensity	84,704.93	6.46
Developed, Open Space	65,262.28	4.98
Herbaceous	30,783.12	2.35
Developed, Medium Intensity	23,021.30	1.75
Open Water	11,783.94	0.90
Evergreen Forest	11,109.61	0.85
Emergent Herbaceous Wetlands	10,011.90	0.76
Barren Land	8,767.50	0.67
Mixed Forest	7,279.01	0.55
Developed, High Intensity	6,659.56	0.51
Shrub/Scrub	3,302.08	0.25
Total	**1,311,794.84**	**100.00**

Table 10. Seney Lake Plain

Land cover	Acres	Percent
Woody Wetlands	494,006.27	55.87
Emergent Herbaceous Wetlands	145,097.45	16.41
Evergreen Forest	100,458.32	11.36
Deciduous Forest	73,846.77	8.35
Mixed Forest	21,788.66	2.46
Herbaceous	19,744.26	2.23
Developed, Open Space	14,045.42	1.59
Open Water	9,783.13	1.11
Developed, Low Intensity	2,725.34	0.31
Shrub/Scrub	2,353.98	0.27
Developed, Medium Intensity	185.79	0.02
Barren Land	106.08	0.01
Cultivated Crops	95.08	0.01
Developed, High Intensity	7.90	< 0.01
Hay/Pasture	2.22	< 0.01
Total	**884,246.69**	**100.00**

Table 11. Southern Green Bay Lobe

Land cover	Acres	Percent
Cultivated Crops	1,368,979.68	49.19
Hay/Pasture	483,072.94	17.36
Deciduous Forest	247,814.57	8.90
Emergent Herbaceous Wetlands	174,252.75	6.26
Woody Wetlands	116,050.26	4.17
Developed, Low Intensity	113,211.01	4.07
Developed, Open Space	98,226.09	3.53
Open Water	88,972.59	3.20
Developed, Medium Intensity	25,503.17	0.92
Shrub/Scrub	24,754.74	0.89
Herbaceous	20,072.57	0.72
Evergreen Forest	9,754.19	0.35
Developed, High Intensity	7,365.52	0.26
Barren Land	2,927.81	0.11
Mixed Forest	2,353.62	0.08
Total	**2,783,311.51**	**100.00**

Table 12. St. Louis Moraines

Land cover	Acres	Percent
Deciduous Forest	882,104.72	53.49
Evergreen Forest	165,700.53	10.05
Woody Wetlands	147,349.37	8.94
Open Water	138,413.34	8.39
Emergent Herbaceous Wetlands	100,326.18	6.08
Hay/Pasture	69,971.00	4.24
Shrub/Scrub	48,778.18	2.96
Herbaceous	43,220.57	2.62
Developed, Open Space	34,644.24	2.10
Cultivated Crops	6,997.51	0.42
Developed, Low Intensity	4,911.50	0.30
Mixed Forest	2,757.54	0.17
Developed, Medium Intensity	1,700.37	0.10
Barren Land	1,584.20	0.10
Developed, High Intensity	627.60	0.04
Total	**1,649,086.82**	**100.00**

Table 13. Superior-Ashland Clay Plain

Land cover	Acres	Percent
Deciduous Forest	721,786.26	55.37
Evergreen Forest	205,804.75	15.79
Hay/Pasture	112,283.00	8.61
Mixed Forest	74,286.05	5.70
Emergent Herbaceous Wetlands	49,445.77	3.79
Developed, Open Space	33,197.04	2.55
Woody Wetlands	30,561.65	2.34
Cultivated Crops	18,878.97	1.45
Herbaceous	16,191.12	1.24
Developed, Low Intensity	14,406.13	1.11
Open Water	12,438.89	0.95
Barren Land	5,737.64	0.44
Shrub/Scrub	5,101.53	0.39
Developed, Medium Intensity	2,869.06	0.22
Developed, High Intensity	659.24	0.05
Total	**1,303,647.11**	**100.00**

Table 14. Toimi Uplands

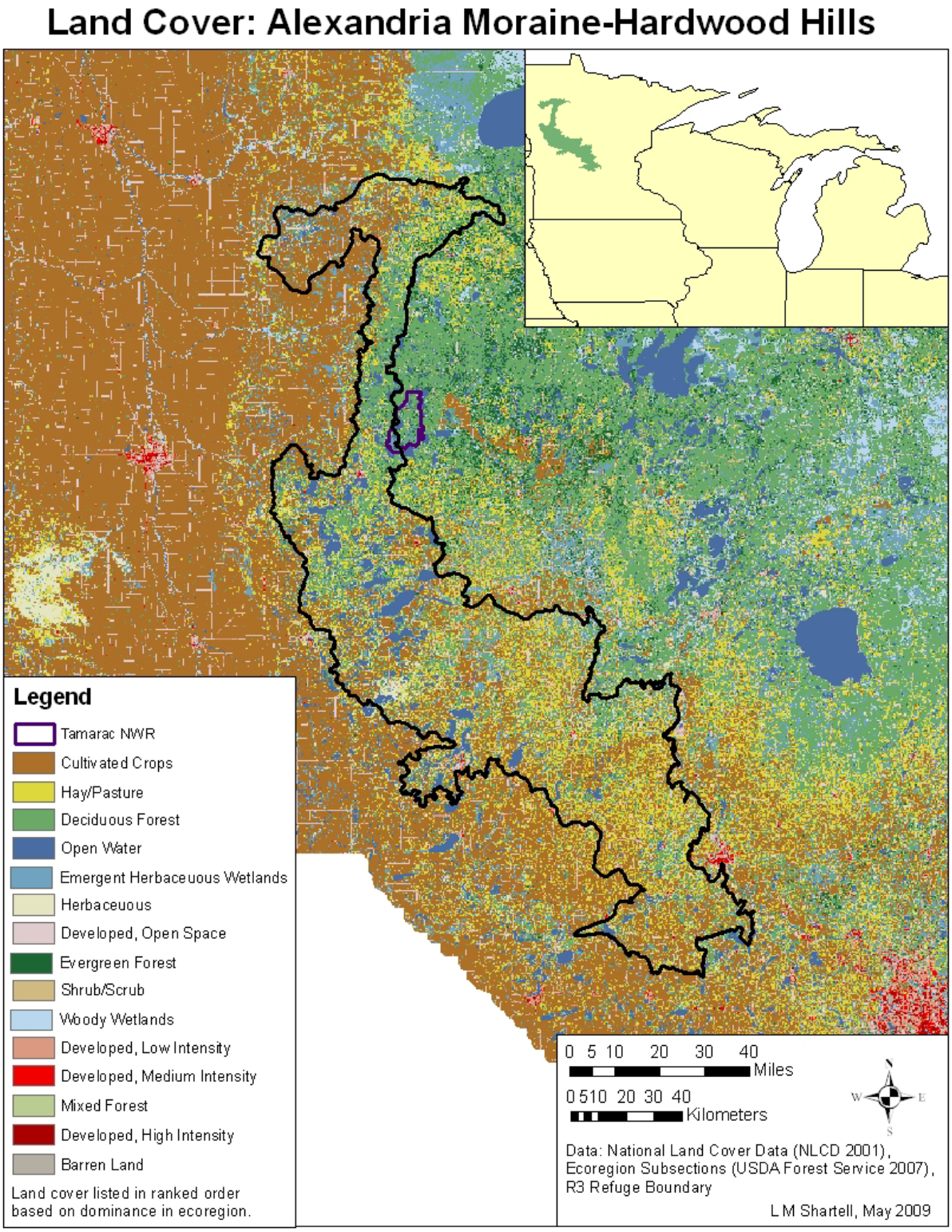
Land cover	Acres	Percent
Deciduous Forest	561,003.75	37.03
Woody Wetlands	361,261.36	23.85
Emergent Herbaceous Wetlands	208,496.49	13.76
Evergreen Forest	121,253.65	8.00
Hay/Pasture	80,849.32	5.34
Herbaceous	65,178.30	4.30
Developed, Open Space	29,749.76	1.96
Open Water	27,962.33	1.85
Shrub/Scrub	25,424.11	1.68
Cultivated Crops	18,397.24	1.21
Mixed Forest	5,557.37	0.37
Developed, Low Intensity	4,672.97	0.31
Barren Land	3,222.04	0.21
Developed, Medium Intensity	1,305.61	0.09
Developed, High Intensity	580.70	0.04
Total	**1,514,914.99**	**100.00**

Table 15. Western Paleozoic Plateau

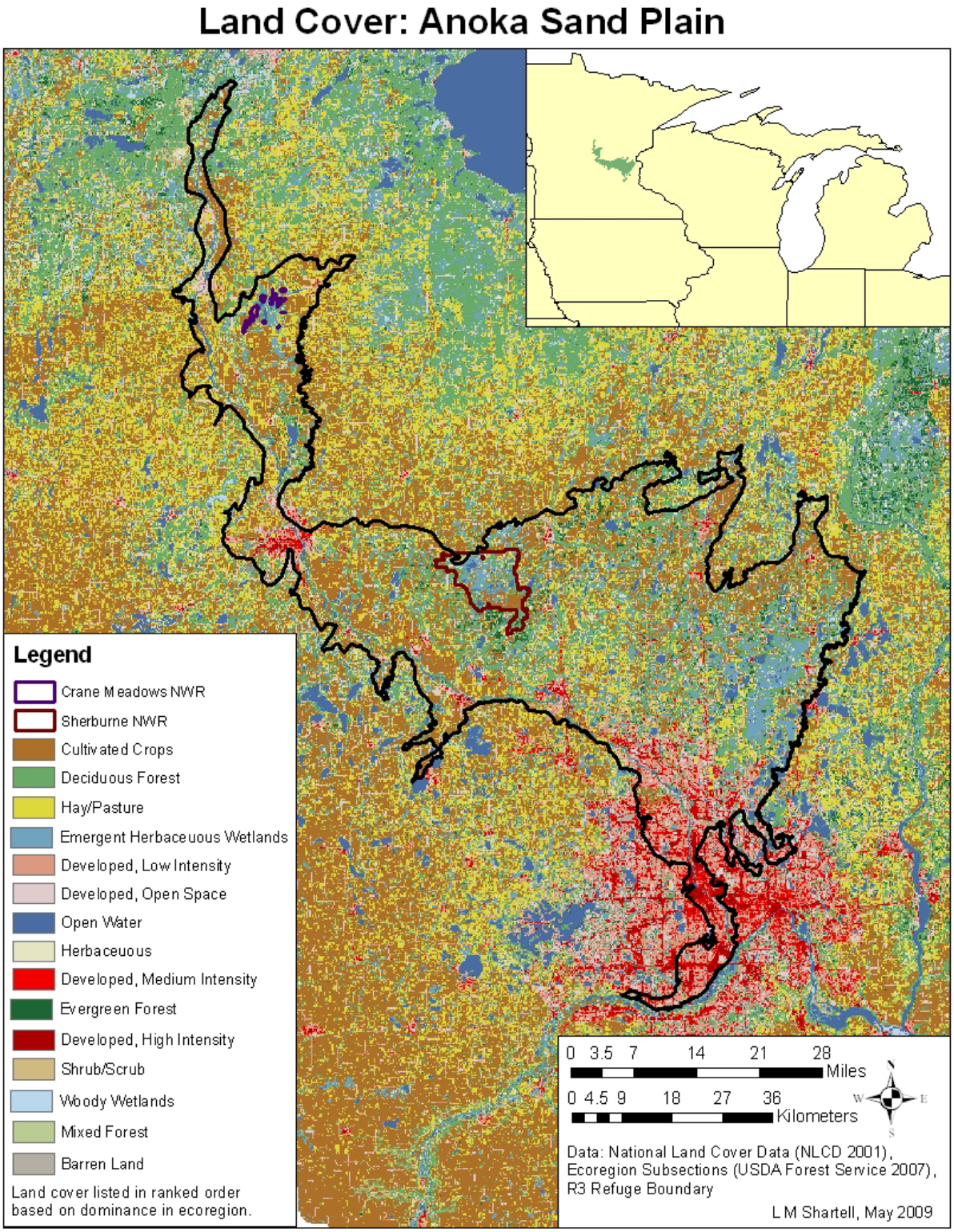
Land cover	Acres	Percent
Cultivated Crops	2,068,878.27	59.06
Developed, Low Intensity	288,464.50	8.23
Developed, Open Space	279,247.91	7.97
Developed, Medium Intensity	233,849.22	6.68
Deciduous Forest	229,734.15	6.56
Hay/Pasture	134,929.83	3.85
Developed, High Intensity	92,579.32	2.64
Woody Wetlands	72,600.52	2.07
Herbaceous	40,673.80	1.16
Open Water	29,183.29	0.83
Emergent Herbaceous Wetlands	17,656.26	0.50
Barren Land	6,584.10	0.19
Evergreen Forest	3,412.78	0.10
Shrub/Scrub	2,707.52	0.08
Mixed Forest	2,534.81	0.07
Total	**3,503,036.32**	**100.00**

Appendix 5. Maps of land cover (NLCD 2001) by ecoregion. Ecoregions are listed alphabetically.

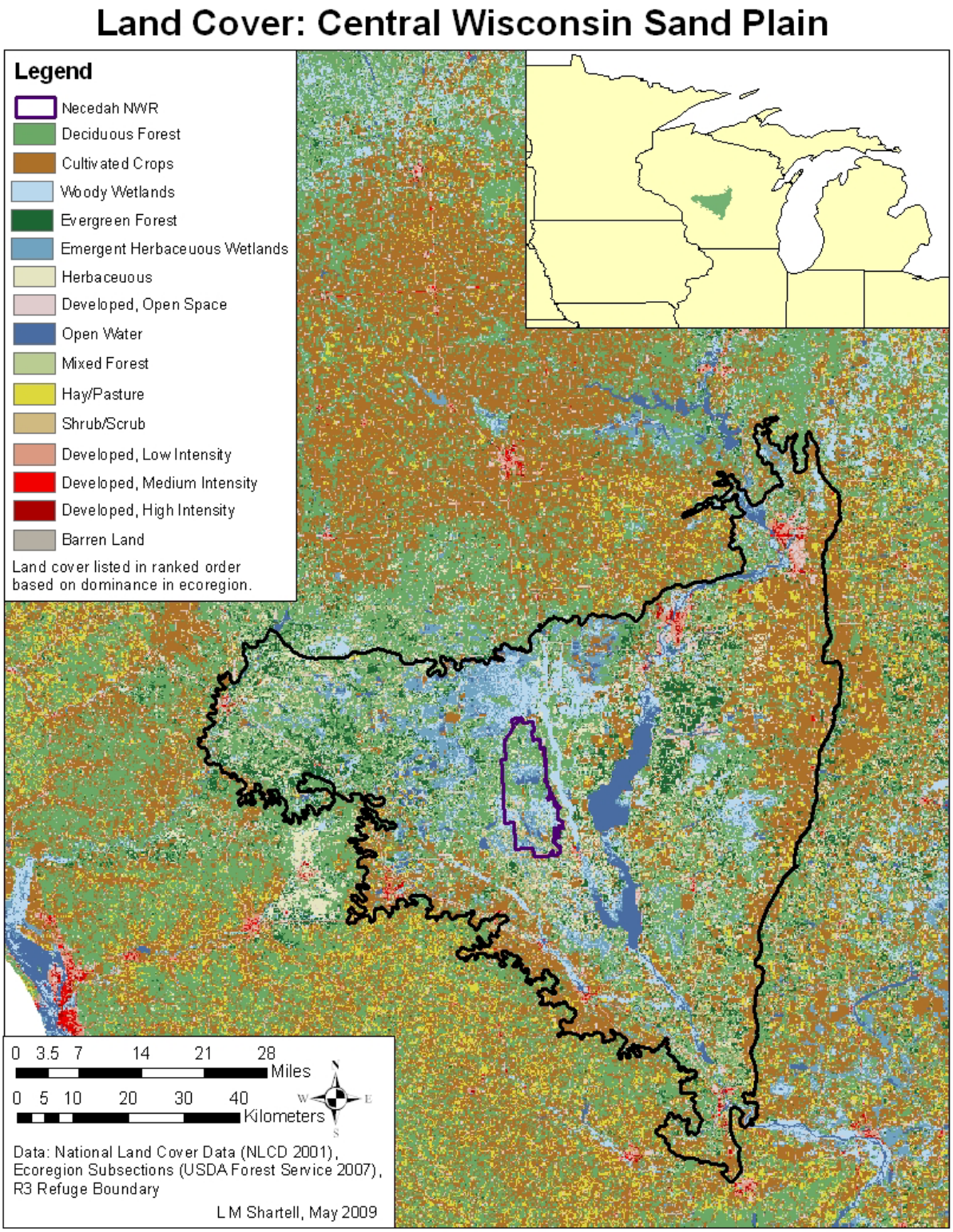
Map 1.



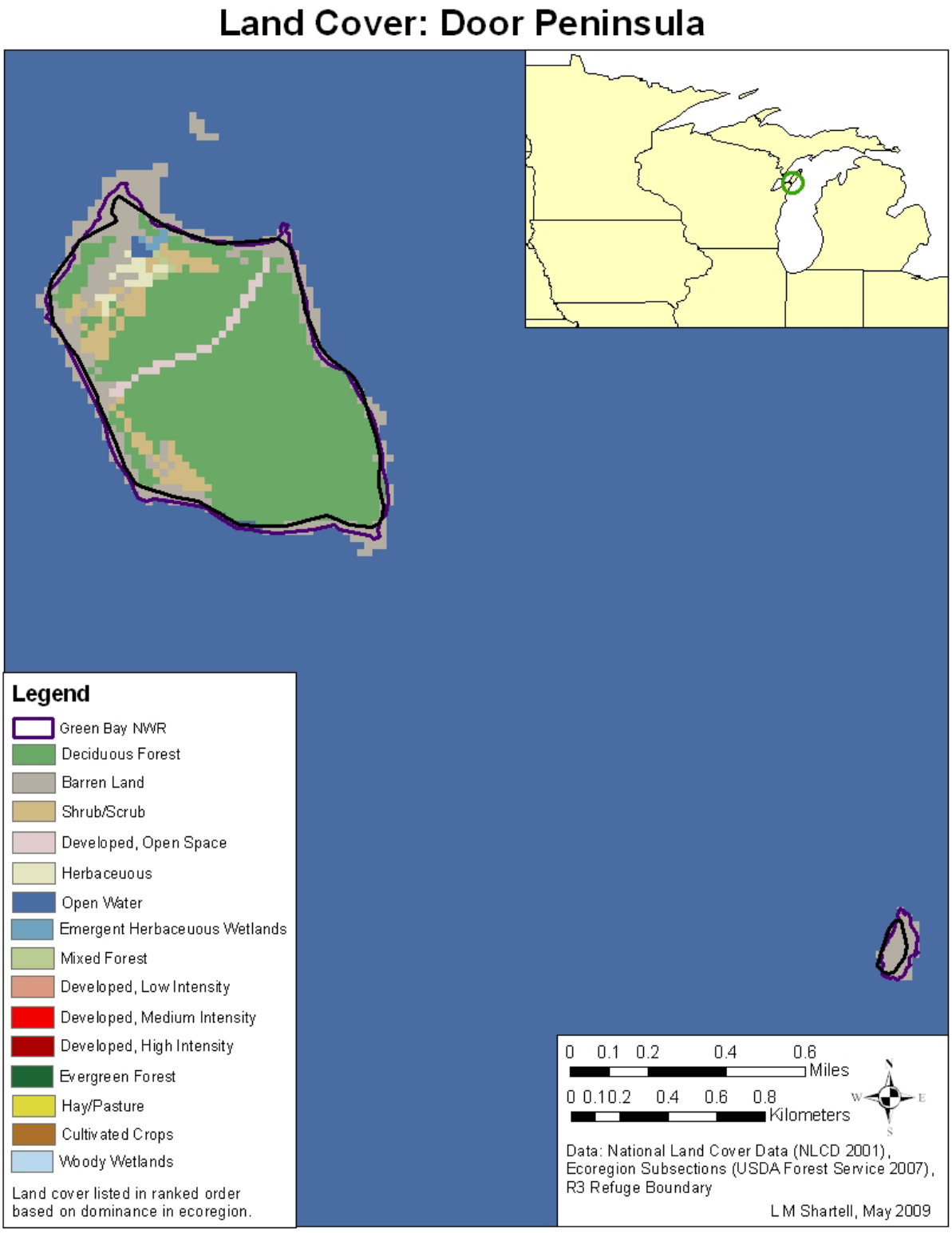
Map 2.


Land Cover: Anoka Sand Plain
Legend
Crane Meadows NWR
Sherburne NWR
Cultivated Crops
Deciduous Forest
Hay/Pasture
Emergent Herbaceuous Wetlands
Developed, Low Intensity
Developed, Open Space
Open Water
Herbaceuous
Developed, Medium Intensity
Evergreen Forest
Developed, High Intensity
Shrub/Scrub
Woody Wetlands
Mixed Forest
Barren Land
Land cover listed in ranked order based on dominance in ecoregion.
0 3.5 7 14 21 28
Miles
0 4.5 9 18 27 36
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 3.

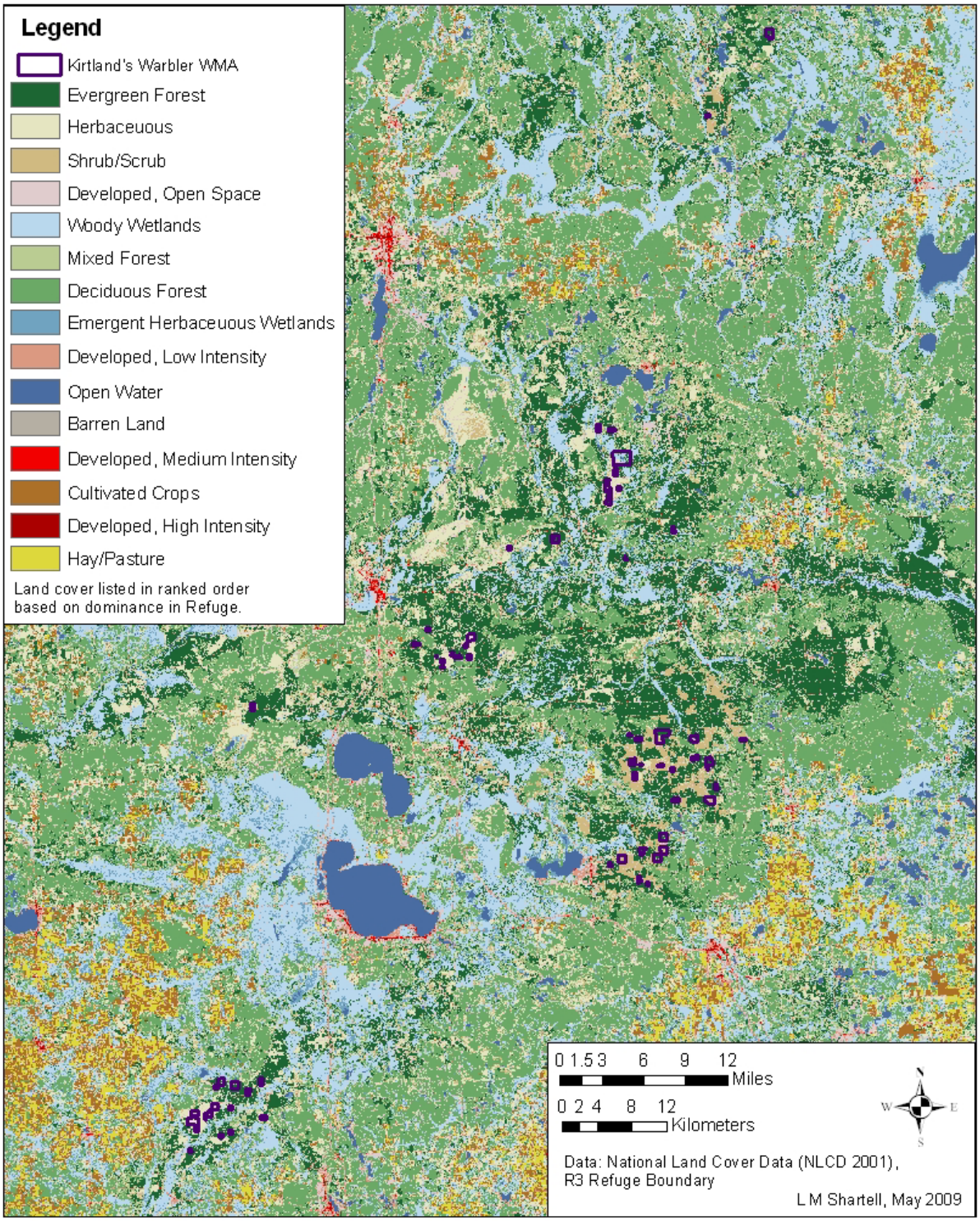

Land Cover: Central Wisconsin Sand Plain
Legend
Necedah NWR
Deciduous Forest
Cultivated Crops
Woody Wetlands
Evergreen Forest
Emergent Herbaceuous Wetlands
Herbaceuous
Developed, Open Space
Open Water
Mixed Forest
Hay/Pasture
Shrub/Scrub
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Land cover listed in ranked order based on dominance in ecoregion.
0 3.5 7 14 21 28
Miles
0 5 10 20 30 40
Kilometers
Data: National Land Cover Data (NLCD 2001), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 4.

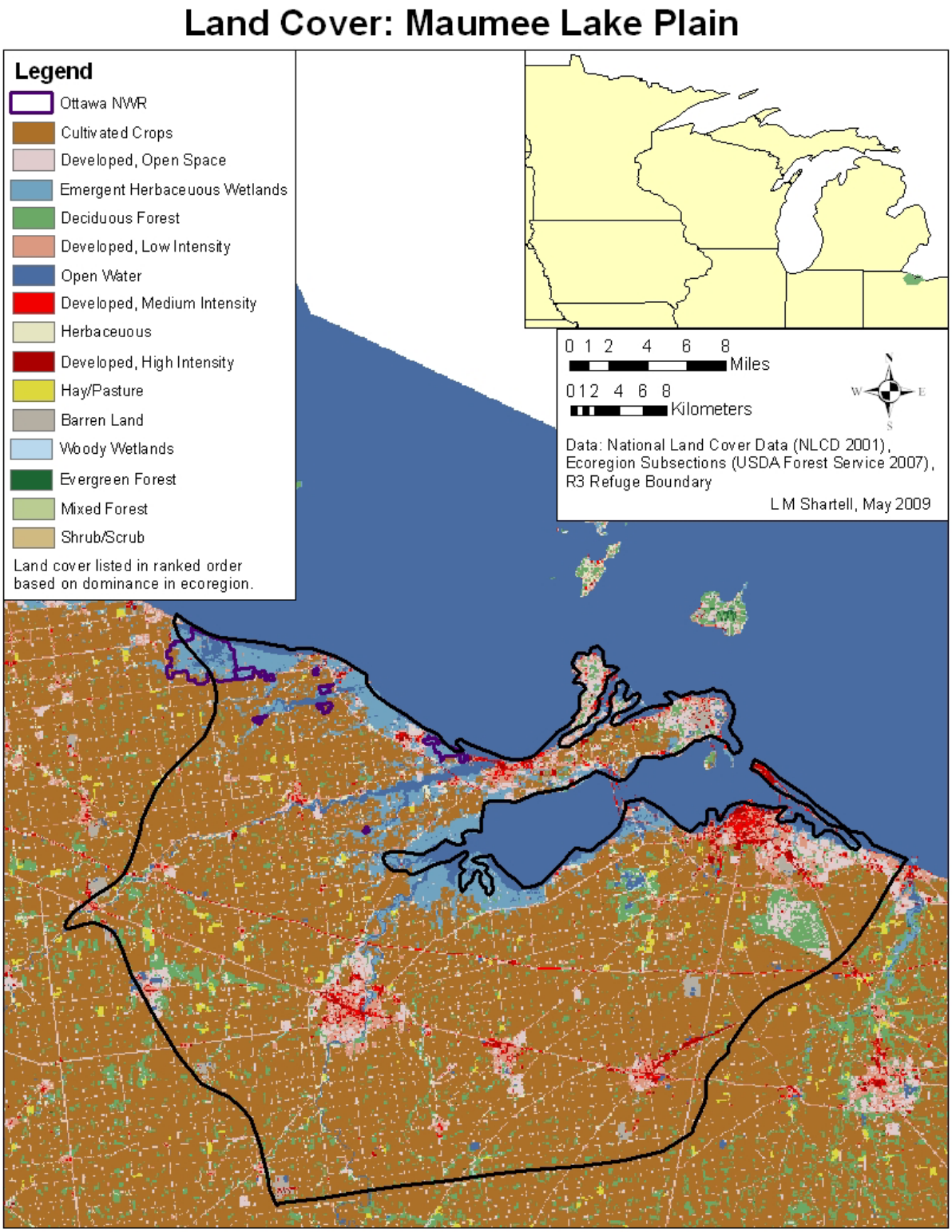

Land Cover: Door Peninsula
Legend
Green Bay NWR
Deciduous Forest
Barren Land
Shrub/Scrub
Developed, Open Space
Herbaceuous
Open Water
Emergent Herbaceuous Wetlands
Mixed Forest
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Evergreen Forest
Hay/Pasture
Cultivated Crops
Woody Wetlands
Land cover listed in ranked order based on dominance in ecoregion.
0 0.1 0.2 0.4 0.6
Miles
0 0.1 0.2 0.4 0.6 0.8
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 5.

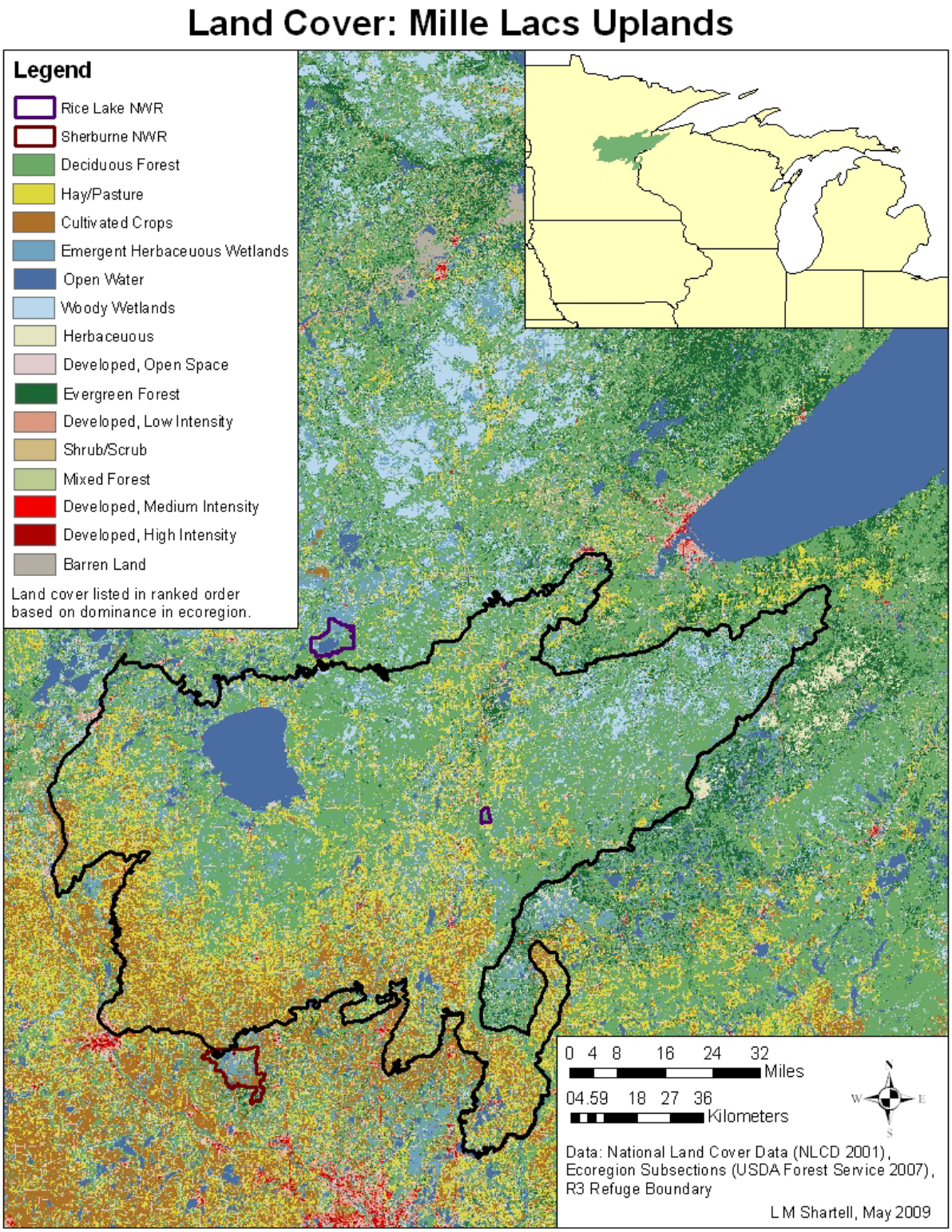
Land Cover: Kirtland's Warbler WMA



Map 6.

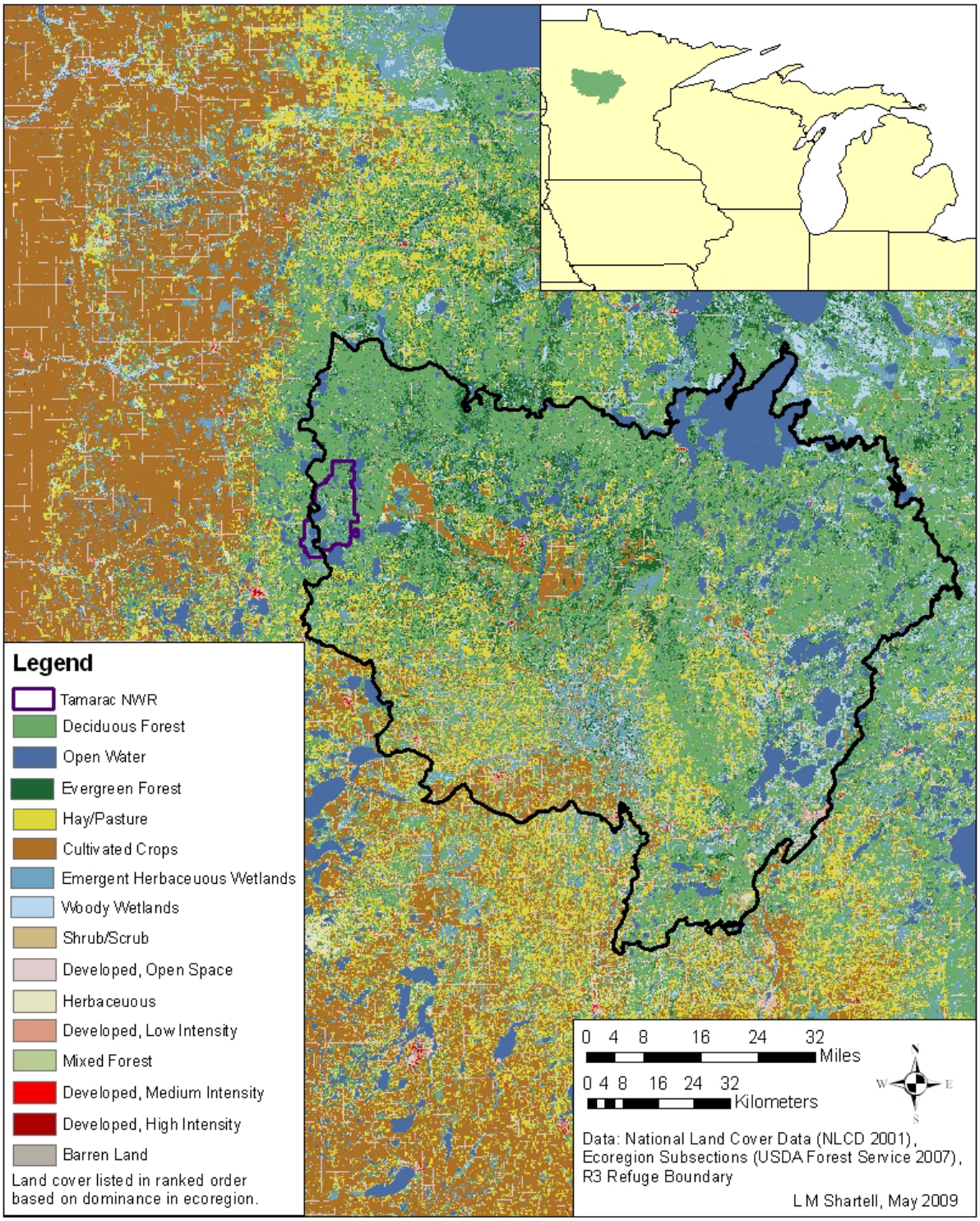

Land Cover: Maumee Lake Plain
Legend
Ottawa NWR
Cultivated Crops
Developed, Open Space
Emergent Herbaceuous Wetlands
Deciduous Forest
Developed, Low Intensity
Open Water
Developed, Medium Intensity
Herbaceuous
Developed, High Intensity
Hay/Pasture
Barren Land
Woody Wetlands
Evergreen Forest
Mixed Forest
Shrub/Scrub
Land cover listed in ranked order based on dominance in ecoregion.
0 1 2 4 6 8 Miles
0 1 2 4 6 8 Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 7.

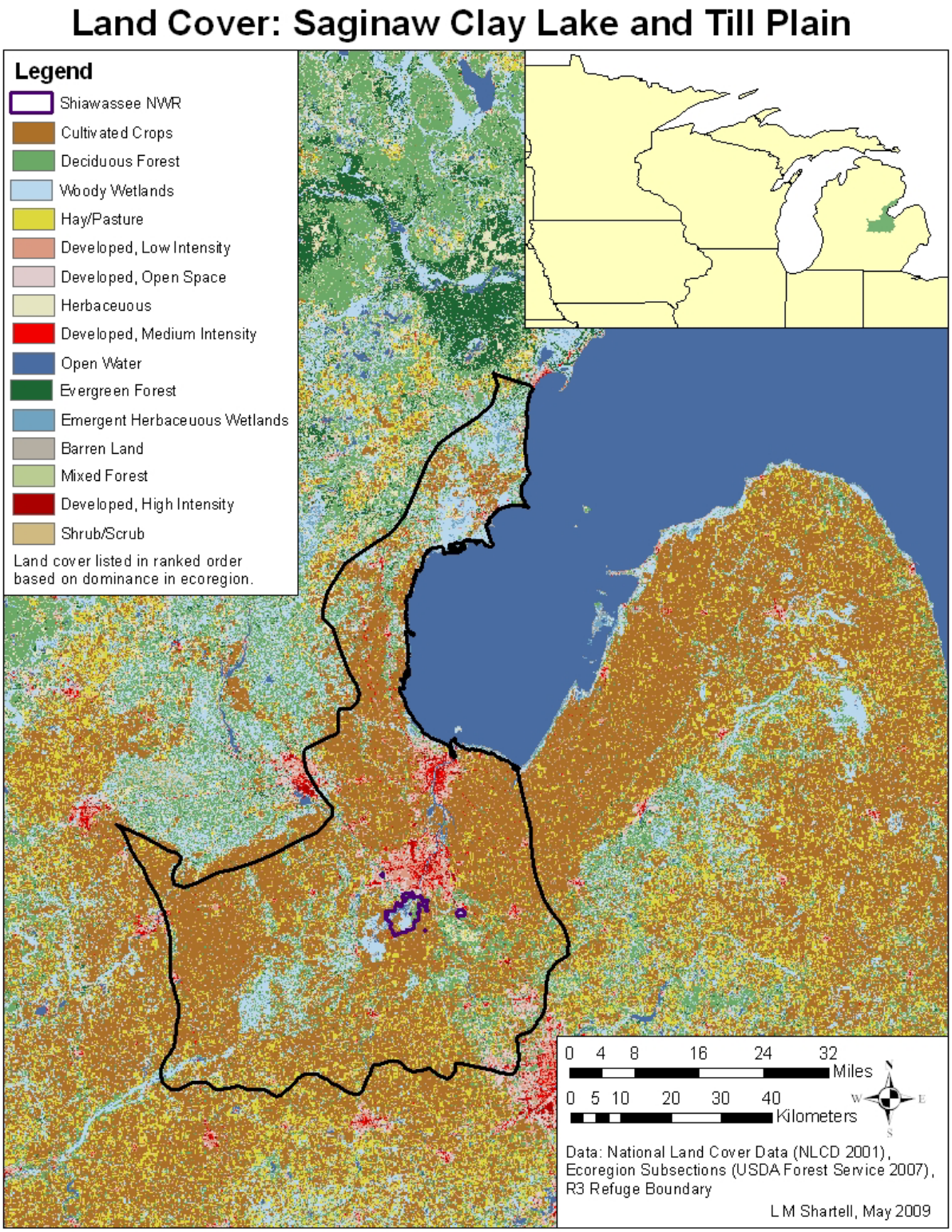

Land Cover: Mille Lacs Uplands
Legend
Rice Lake NWR
Sherburne NWR
Deciduous Forest
Hay/Pasture
Cultivated Crops
Emergent Herbaceuous Wetlands
Open Water
Woody Wetlands
Herbaceuous
Developed, Open Space
Evergreen Forest
Developed, Low Intensity
Shrub/Scrub
Mixed Forest
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Land cover listed in ranked order based on dominance in ecoregion.
0 4 8 16 24 32
Miles
04.59 18 27 36
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 8.

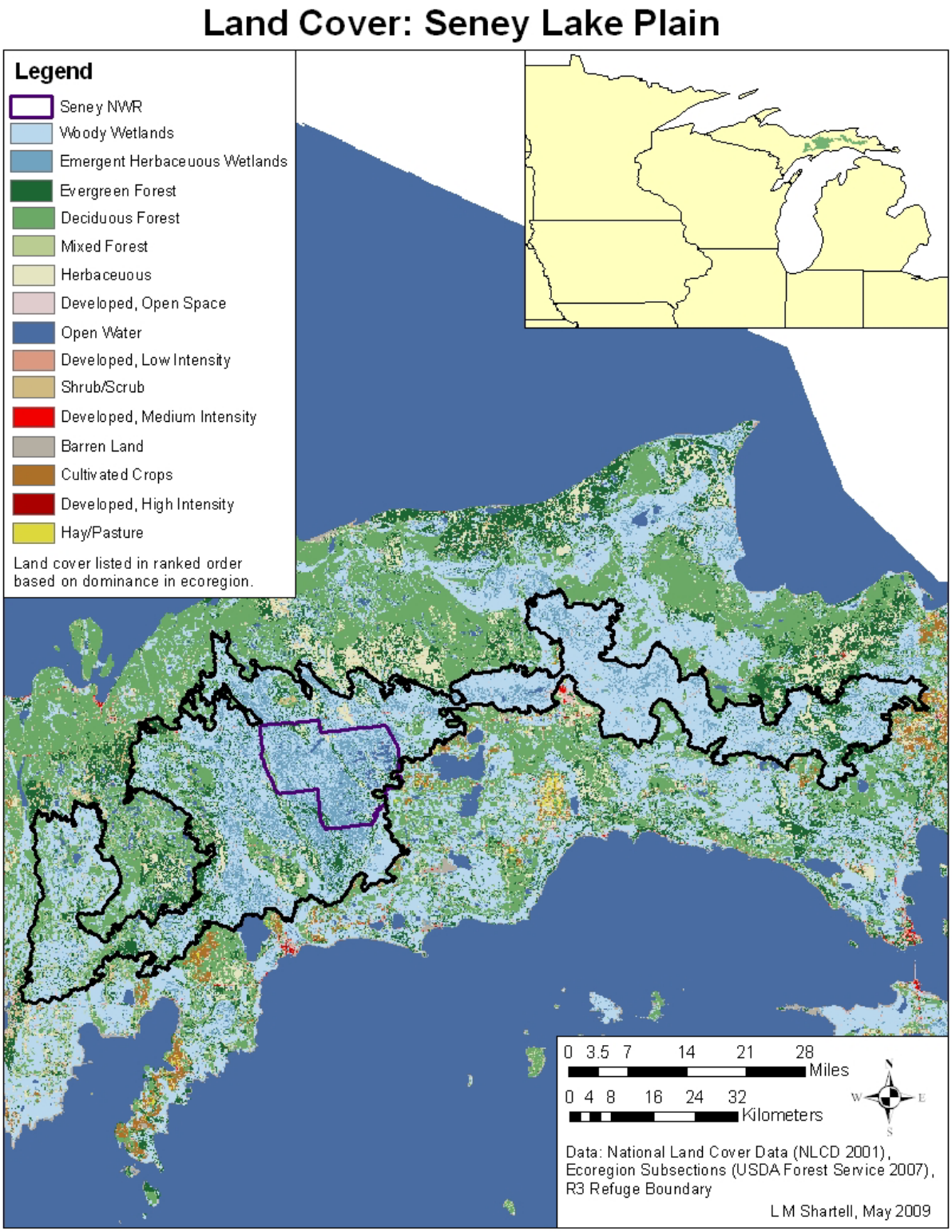
Land Cover: Pine Moraine and Outwash Plains



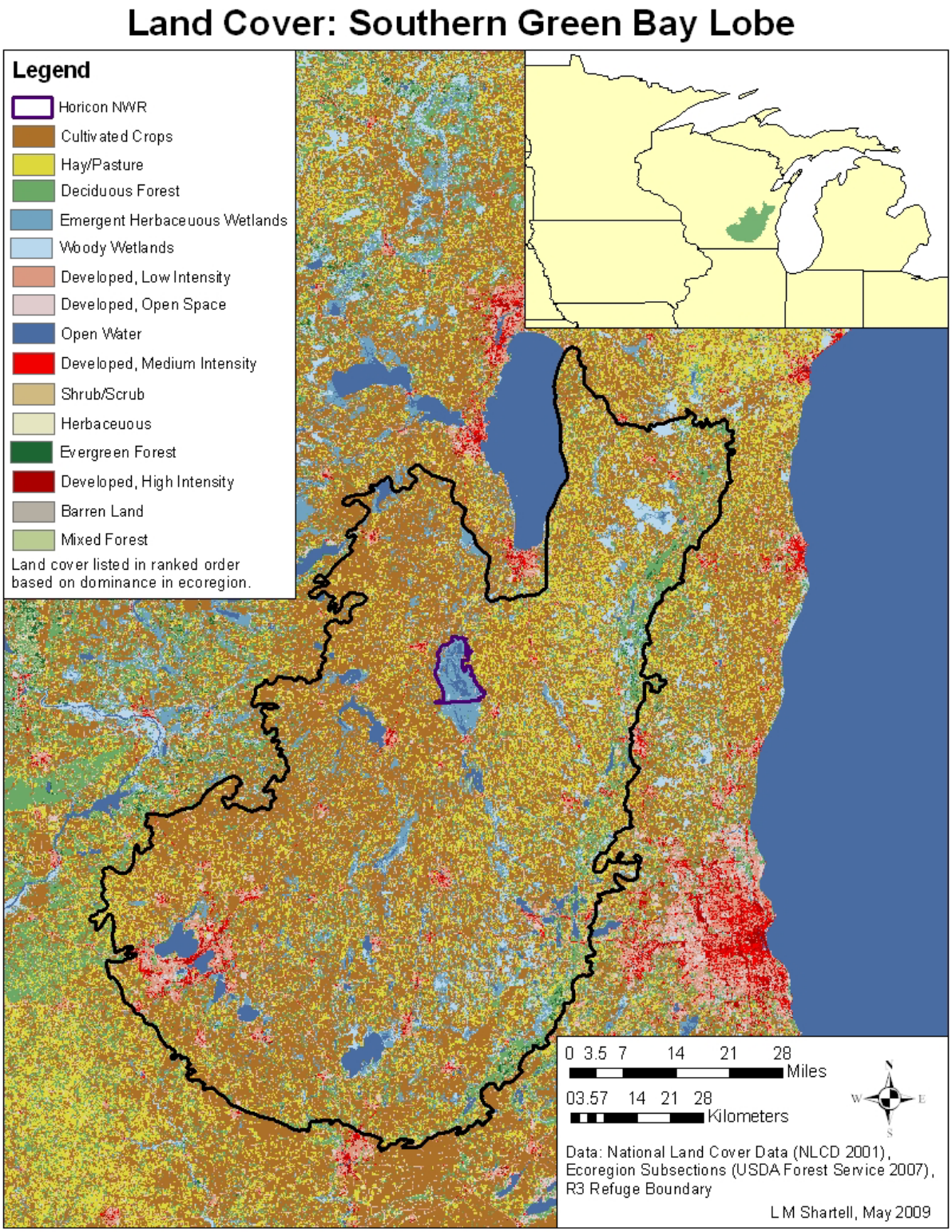
Map 9.


Land Cover: Saginaw Clay Lake and Till Plain
Legend
Shiawassee NWR
Cultivated Crops
Deciduous Forest
Woody Wetlands
Hay/Pasture
Developed, Low Intensity
Developed, Open Space
Herbaceuous
Developed, Medium Intensity
Open Water
Evergreen Forest
Emergent Herbaceuous Wetlands
Barren Land
Mixed Forest
Developed, High Intensity
Shrub/Scrub
Land cover listed in ranked order based on dominance in ecoregion.
0 4 8 16 24 32
Miles
0 5 10 20 30 40
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

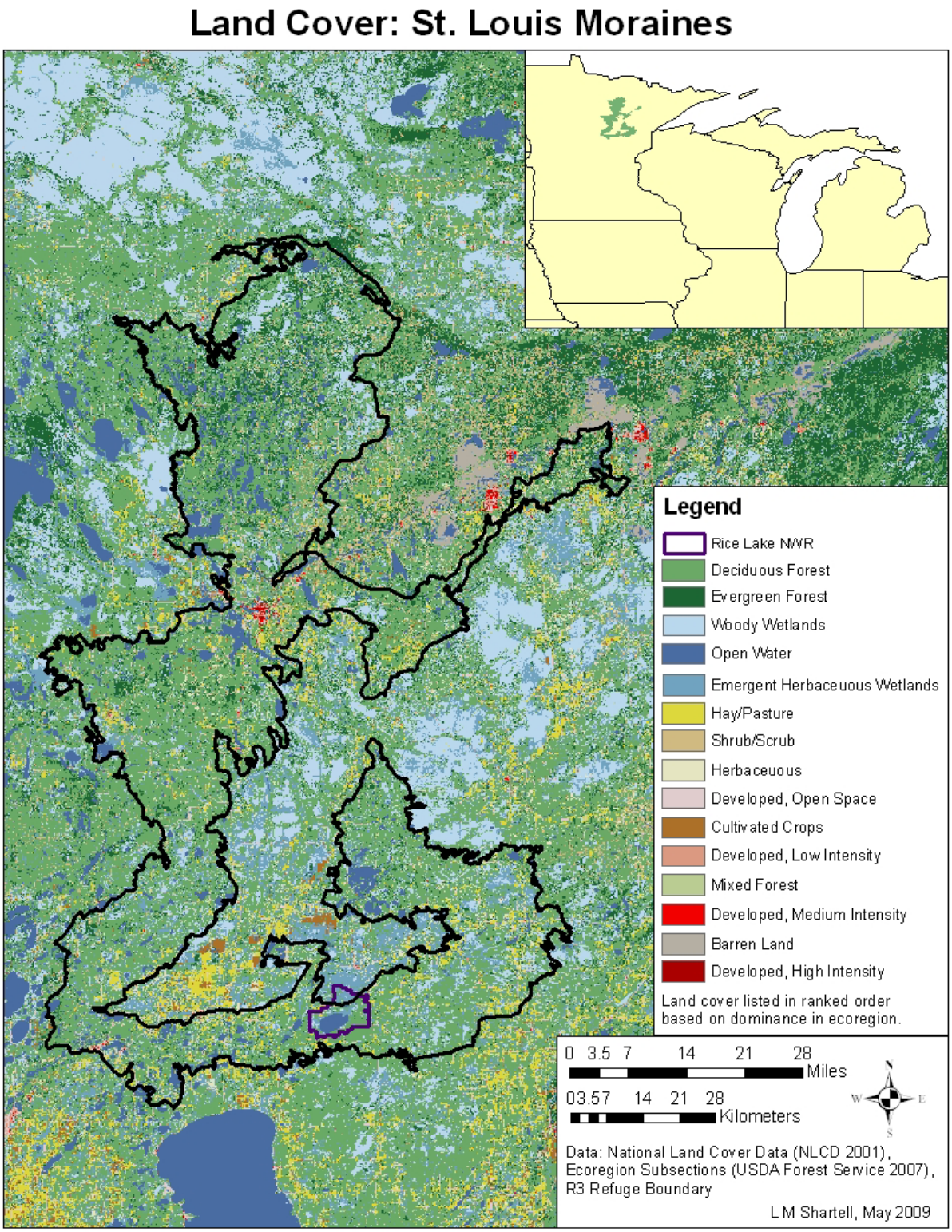
Map 10.


Land Cover: Seney Lake Plain
Legend
Seney NWR
Woody Wetlands
Emergent Herbaceuous Wetlands
Evergreen Forest
Deciduous Forest
Mixed Forest
Herbaceuous
Developed, Open Space
Open Water
Developed, Low Intensity
Shrub/Scrub
Developed, Medium Intensity
Barren Land
Cultivated Crops
Developed, High Intensity
Hay/Pasture
Land cover listed in ranked order based on dominance in ecoregion.
0 3.5 7 14 21 28
Miles
0 4 8 16 24 32
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

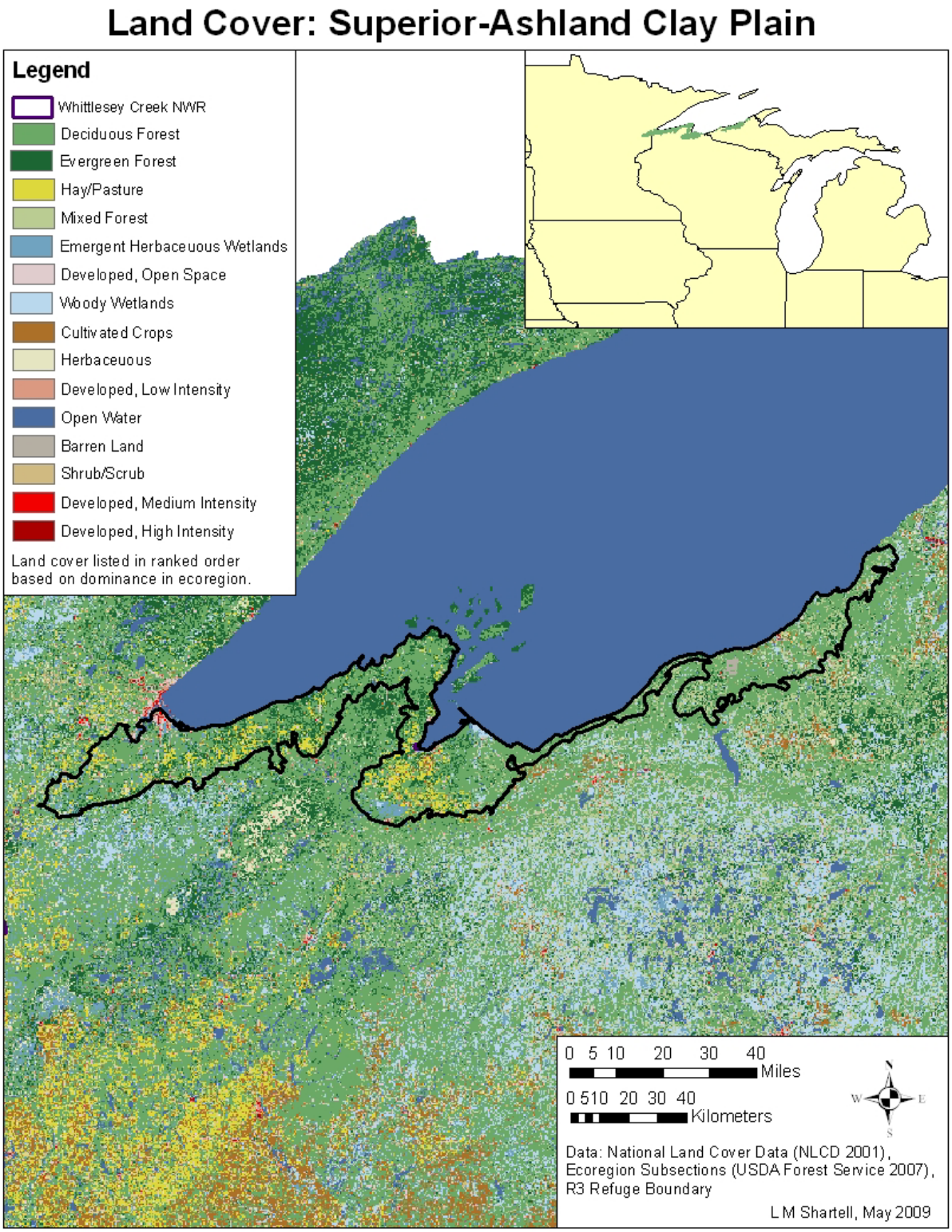
Map 11.


Land Cover: Southern Green Bay Lobe
Legend
Horicon NWR
Cultivated Crops
Hay/Pasture
Deciduous Forest
Emergent Herbaceuous Wetlands
Woody Wetlands
Developed, Low Intensity
Developed, Open Space
Open Water
Developed, Medium Intensity
Shrub/Scrub
Herbaceuous
Evergreen Forest
Developed, High Intensity
Barren Land
Mixed Forest
Land cover listed in ranked order based on dominance in ecoregion.
0 3.5 7 14 21 28
Miles
03.57 14 21 28
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

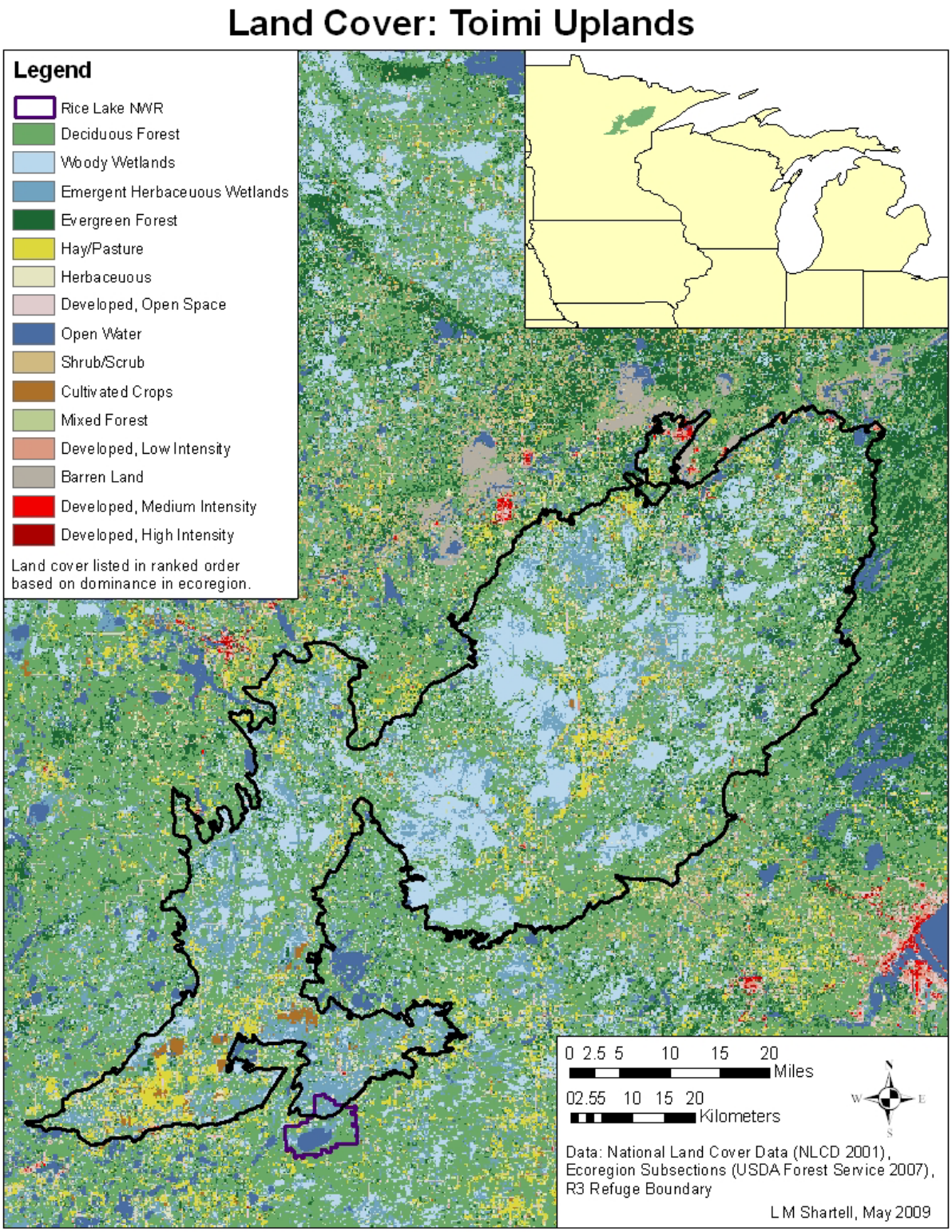
Map 12.


Land Cover: St. Louis Moraines
Legend
Rice Lake NWR
Deciduous Forest
Evergreen Forest
Woody Wetlands
Open Water
Emergent Herbaceuous Wetlands
Hay/Pasture
Shrub/Scrub
Herbaceuous
Developed, Open Space
Cultivated Crops
Developed, Low Intensity
Mixed Forest
Developed, Medium Intensity
Barren Land
Developed, High Intensity
Land cover listed in ranked order based on dominance in ecoregion.
0 3.5 7 14 21 28
Miles
03.57 14 21 28
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 13.

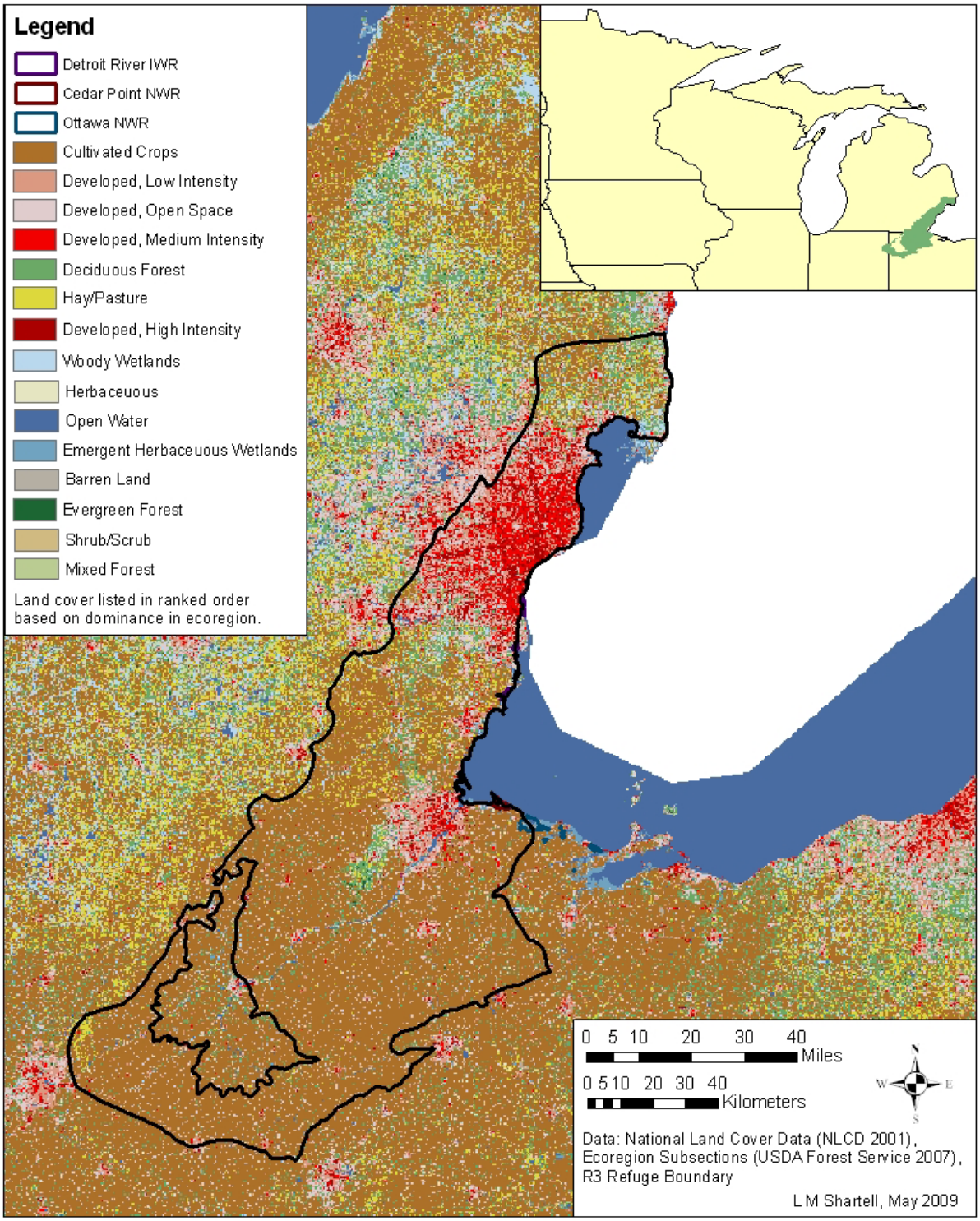

Land Cover: Superior-Ashland Clay Plain
Legend
Whittlesey Creek NWR
Deciduous Forest
Evergreen Forest
Hay/Pasture
Mixed Forest
Emergent Herbaceuous Wetlands
Developed, Open Space
Woody Wetlands
Cultivated Crops
Herbaceuous
Developed, Low Intensity
Open Water
Barren Land
Shrub/Scrub
Developed, Medium Intensity
Developed, High Intensity
Land cover listed in ranked order based on dominance in ecoregion.
0 5 10 20 30 40
Miles
0 510 20 30 40
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 14.


Land Cover: Toimi Uplands
Legend
Rice Lake NWR
Deciduous Forest
Woody Wetlands
Emergent Herbaceuous Wetlands
Evergreen Forest
Hay/Pasture
Herbaceuous
Developed, Open Space
Open Water
Shrub/Scrub
Cultivated Crops
Mixed Forest
Developed, Low Intensity
Barren Land
Developed, Medium Intensity
Developed, High Intensity
Land cover listed in ranked order based on dominance in ecoregion.
0 2.5 5 10 15 20
Miles
02.55 10 15 20
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), Ecoregion Subsections (USDA Forest Service 2007), R3 Refuge Boundary
L M Shartell, May 2009

Map 15.

Land Cover: Western Paleozoic Plateau



Appendix 6. Soil series (STATSGO2, NRCS) and their characteristics by ecoregion, listed in ranked order by area. Ecoregions are listed alphabetically.

Table 1. Alexandria Moraine-Hardwood Hills

Soil series	Texture	Drainage	Acres	Percent
Chapett	fine-loamy	Well drained	475,032.45	13.58
Sverdrup	sandy	Well drained	367,425.29	10.51
Waukon	fine-loamy	Well drained	342,307.65	9.79
Blowers	coarse-loamy	Moderately well drained	225,654.80	6.45
Cushing	fine-loamy	Well drained	184,381.37	5.27
Snellman	fine-loamy	Well drained	160,792.98	4.60
Dorset	coarse-loamy	Well drained	148,422.36	4.24
Naytahwaush	fine	Well drained	146,700.55	4.20
Brainerd	coarse-loamy	Moderately well drained	135,001.93	3.86
Hubbard	sandy	Excessively drained	125,467.28	3.59
Markey	sandy or sandy-skeletal	Very poorly drained	115,474.57	3.30
Koronis	fine-loamy	Well drained	109,915.84	3.14
Nebish	fine-loamy	Well drained	102,947.24	2.94
Water	-	-	102,020.96	2.92
Estherville	sandy	Somewhat excessively drained	98,659.89	2.82
Kandota	fine-loamy	Well drained	96,459.74	2.76
Growton	coarse-loamy	Somewhat poorly drained	76,203.67	2.18
Percy	coarse-loamy	Poorly drained	73,623.71	2.11
Forman	fine-loamy	Well drained	65,856.87	1.88
Gonvick	fine-loamy	Moderately well drained	58,124.64	1.66
Menahga	not used	Excessively drained	46,105.89	1.32
Barnes	fine-loamy	Well drained	37,351.57	1.07
Heimdal	coarse-loamy	Well drained	33,996.72	0.97
Fairhaven	fine-loamy over sandy	Well drained	31,549.39	0.90
Hattie	fine	Moderately well drained	31,542.43	0.90
Mahtomedi	not used	Excessively drained	29,186.57	0.83
Lohnes	sandy	Moderately well drained	23,573.63	0.67
Wadenill	coarse-loamy	Well drained	14,938.36	0.43
Grimstad	sandy over loamy	Somewhat poorly drained	14,908.21	0.43
Madelia	fine-silty	Poorly drained	8,276.65	0.24
Nymore	not used	Excessively drained	4,194.17	0.12
Andrusia	loamy	Well drained	3,773.86	0.11
Ulen	sandy	Somewhat poorly drained	3,764.50	0.11
Lester	fine-loamy	Well drained	1,930.52	0.06
Vallers	fine-loamy	Poorly drained	647.27	0.02
Cathro	loamy	Very poorly drained	408.86	0.01
Ves	fine-loamy	Well drained	147.40	< 0.01

Suomi	fine	Moderately well drained	85.76	< 0.01
Sol	fine-loamy	Well drained	7.46	< 0.01
Total			**3,496,863.04**	**100.00**

Table 2. Anoka Sand Plain

Soil series	Texture	Drainage	Acres	Percent
Zimmerman	not used	Excessively drained	507,140.37	42.22
Hubbard	sandy	Excessively drained	382,003.66	31.81
Isanti	sandy	Poorly drained	49,220.82	4.10
Heyder	coarse-loamy	Well drained	46,881.62	3.90
Burkhardt	sandy	Somewhat excessively drained	34,014.77	2.83
Estherville	sandy	Somewhat excessively drained	25,949.36	2.16
Kost	sandy	Excessively drained	19,972.29	1.66
Nymore	not used	Excessively drained	18,229.24	1.52
Pomroy	loamy	Well drained	16,025.25	1.33
Pierz	coarse-loamy	Well drained	15,452.53	1.29
Cushing	fine-loamy	Well drained	12,795.17	1.07
Greenwood	not used	Very poorly drained	9,280.43	0.77
Braham	loamy	Well drained	7,909.52	0.66
Brainerd	coarse-loamy	Moderately well drained	7,875.07	0.66
Hayden	fine-loamy	Well drained	7,826.10	0.65
Lester	fine-loamy	Well drained	6,595.80	0.55
Sartell	not used	Excessively drained	6,321.72	0.53
Mora	coarse-loamy	Moderately well drained	6,192.72	0.52
Mahtomedi	not used	Excessively drained	4,474.97	0.37
Dorset	coarse-loamy	Well drained	3,364.81	0.28
Winterfield	not used	Somewhat poorly drained	2,454.65	0.20
Sverdrup	sandy	Well drained	2,097.55	0.17
Loxley	not used	Very poorly drained	1,954.51	0.16
Bluffton	fine-loamy	Very poorly drained	1,787.81	0.15
Chaska	fine-loamy	Somewhat poorly drained	1,267.76	0.11
Growton	coarse-loamy	Somewhat poorly drained	1,086.16	0.09
Dalbo	fine	Moderately well drained	644.56	0.05
Waukegan	fine-silty over sandy	Well drained	567.69	0.05
Chetek	coarse-loamy	Somewhat excessively drained	553.39	0.05
Antigo	coarse-loamy over sandy	Well drained	519.71	0.04
Menahga	not used	Excessively drained	220.63	0.02
Santiago	coarse-loamy	Well drained	196.66	0.02
Copaston	loamy	Well drained	195.97	0.02
Total			**1,201,073.27**	**100.00**

Table 3. Central Wisconsin Sand Plain

Soil series	Texture	Drainage	Acres	Percent
Newson	not used	Poorly drained	657,222.46	40.64
Plainfield	not used	Excessively drained	418,521.18	25.88
Boone	not used	Excessively drained	122,297.52	7.56
Loxley	not used	Very poorly drained	63,803.51	3.95
Fordum	coarse-loamy	Poorly drained	56,976.52	3.52
Billett	coarse-loamy	Well drained	50,240.00	3.11
Plainbo	not used	Excessively drained	47,273.87	2.92
Water	fine-loamy over sandy	Poorly drained	41,383.83	2.56
Ludington	sandy over loamy	Moderately well drained	32,708.51	2.02
La Farge	fine-silty	Well drained	27,613.19	1.71
Richford	loamy	Well drained	25,465.86	1.57
Markey	sandy or sandy-skeletal	Very poorly drained	21,108.51	1.31
Dickinson	coarse-loamy	Well drained	18,620.96	1.15
Point	fine-loamy	Somewhat poorly drained	15,820.63	0.98
Meadland	fine-loamy	Somewhat poorly drained	4,879.03	0.30
Vesper	fine-loamy over sandy	Poorly drained	4,018.27	0.25
Gotham	not used	Well drained	3,629.98	0.22
Briggsville	fine	Well drained	3,058.97	0.19
Seaton	fine-silty	Well drained	1,904.11	0.12
Kennan	coarse-loamy	Well drained	400.24	0.02
Fenwood	fine-loamy	Well drained	95.12	0.01
Eleva	coarse-loamy	Well drained	40.81	< 0.01
Houghton	not used	Very poorly drained	24.19	< 0.01
Total			**1,617,107.25**	**100.00**

Table 4. Door Peninsula

Soil series	Texture	Drainage	Acres	Percent
Longrie	coarse-loamy	Well drained	262.81	100.00
Total			**262.81**	**100.00**

Table 5. Kirtland's Warbler High Sand Plains

Soil series	Texture	Drainage	Acres	Percent
Rubicon	sandy	Excessively drained	812,937.88	43.20
Grayling	not used	Excessively drained	315,687.01	16.78
Lupton	not used	Very poorly drained	207,554.18	11.03
Graycalm	not used	Somewhat excessively drained	164,975.02	8.77
Blue Lake	sandy	Well drained	76,521.56	4.07
Au Gres	sandy	Somewhat poorly drained	68,911.61	3.66
Nester	fine	Moderately well drained	37,915.28	2.01
Water	sandy	Well drained	35,468.69	1.88
Histosols	not used	Very poorly drained	31,238.87	1.66
Kalkaska	sandy	Somewhat excessively drained	23,279.31	1.24
Emmet	coarse-loamy	Well drained	22,287.91	1.18
Iosco	sandy over loamy	Somewhat poorly drained	19,448.21	1.03
Coloma	not used	Excessively drained	15,340.22	0.82
Grattan	sandy	Excessively drained	10,661.37	0.57
Cathro	loamy	Very poorly drained	10,318.03	0.55
Spinks	sandy	Well drained	9,314.01	0.49
Remus	fine-loamy	Well drained	6,932.82	0.37
Mancelona	sandy	Somewhat excessively drained	4,911.33	0.26
Houghton	not used	Very poorly drained	4,122.37	0.22
Pinconning	sandy over clayey	Poorly drained	3,255.92	0.17
Perrinton	fine	Well drained	495.15	0.03
Mecosta	sandy-skeletal	Somewhat excessively drained	189.04	0.01
Total			**1,881,765.78**	**100.00**

Table 6. Maumee Lake Plain

Soil series	Texture	Drainage	Acres	Percent
Toledo	fine	Very poorly drained	122,311.42	27.67
Kibbie	fine-loamy	Somewhat poorly drained	74,260.96	16.80
Nappanee	fine	Somewhat poorly drained	69,796.86	15.79
Lenawee	fine	Poorly drained	60,248.41	13.63
Castalia	loamy-skeletal	Well drained	32,267.19	7.30
Spinks	sandy	Well drained	27,446.94	6.21
Pewamo	fine	Poorly drained	27,329.88	6.18
Glynwood	fine	Moderately well drained	10,162.01	2.30
Allis	fine	Poorly drained	8,911.09	2.02
Sandusky	fine-loamy	Very poorly drained	5,665.77	1.28
Bennington	fine	Somewhat poorly drained	1,008.85	0.23
Millsdale	fine	Very poorly drained	981.39	0.22
Water	fine	Very poorly drained	857.26	0.19
Mahoning	fine	Somewhat poorly drained	712.21	0.16
Total			**441,960.25**	**100.00**

Table 7. Mille Lacs Uplands

Soil series	Texture	Drainage	Acres	Percent
Mora	sandy	Very poorly drained	828,393.88	21.60
Ahmeek	coarse-loamy	Well drained	556,390.95	14.51
Greenwood	not used	Very poorly drained	420,984.28	10.98
Brainerd	loamy	Well drained	301,558.74	7.86
Omega	sandy	Somewhat excessively drained	274,831.39	7.17
Duluth	fine-loamy	Well drained	250,139.18	6.52
Cushing	fine-loamy	Well drained	190,827.49	4.98
Chetek	loamy	Well drained	142,906.32	3.73
Water	sandy	Excessively drained	141,040.46	3.68
Bluffton	not used	Poorly drained	78,726.45	2.05
Loxley	sandy	Very poorly drained	75,345.50	1.96
Dalbo	fine-loamy	Well drained	73,272.70	1.91
Rosholt	coarse-loamy	Well drained	68,089.28	1.78
Parent	very-fine	Moderately well drained	54,990.64	1.43
Cloquet	loamy	Well drained	52,417.03	1.37
Rifle	very-fine	Moderately well drained	40,092.59	1.05
Pomroy	very-fine	Moderately well drained	35,817.77	0.93
Alstad	coarse-loamy	Well drained	35,284.77	0.92
Bushville	loamy	Well drained	29,609.64	0.77
Zimmerman	sandy	Excessively drained	25,013.16	0.65
Automba	coarse-loamy over sandy	Well drained	24,427.13	0.64

Mahtomedi	sandy	Very poorly drained	23,741.48	0.62
Sayner	sandy	Excessively drained	20,998.48	0.55
Winterfield	sandy	Excessively drained	20,093.32	0.52
Kinross	sandy	Very poorly drained	15,215.59	0.40
Ontonagon	very-fine	Moderately well drained	14,156.44	0.37
Braham	loamy	Well drained	11,970.29	0.31
Hubbard	not used	Very poorly drained	7,987.88	0.21
Cromwell	loamy	Well drained	7,811.40	0.20
Sartell	coarse-loamy	Well drained	7,093.01	0.18
Barronett variant	not used	Poorly drained	1,709.99	0.04
Antigo	coarse-loamy over sandy	Well drained	999.02	0.03
Nemadji	sandy	Very poorly drained	987.47	0.03
Pierz	very-fine	Moderately well drained	921.20	0.02
Kost	sandy	Very poorly drained	718.86	0.02
Santiago	coarse-loamy	Well drained	260.61	0.01
Spooner	sandy	Excessively drained	110.07	< 0.01
Total			**3,834,934.48**	**100.00**

Table 8. Pine Moraine and Outwash Plains

Soil series	Texture	Drainage	Acres	Percent
Snellman	fine-loamy	Well drained	452,962.73	14.97
Mahtomedi	not used	Excessively drained	413,698.94	13.67
Warba	fine-loamy	Moderately well drained	268,406.87	8.87
Chetek	coarse-loamy	Somewhat excessively drained	246,169.87	8.13
Brainerd	coarse-loamy	Moderately well drained	234,312.68	7.74
Cushing	fine-loamy	Well drained	232,668.76	7.69
Blowers	coarse-loamy	Moderately well drained	187,158.62	6.18
Water			174,412.40	5.76
Dorset	coarse-loamy	Well drained	150,491.55	4.97
Markey	sandy or sandy-skeletal	Very poorly drained	134,933.32	4.46
Huntersville	loamy	Moderately well drained	128,279.48	4.24
Menahga	not used	Excessively drained	119,680.25	3.95
Nymore	not used	Excessively drained	84,358.75	2.79
Chapett	fine-loamy	Well drained	73,854.27	2.44
Nebish	fine-loamy	Well drained	31,616.55	1.04
Zimmerman	not used	Excessively drained	20,737.62	0.69
Andrusia	loamy	Well drained	19,970.35	0.66
Rifle	not used	Very poorly drained	15,508.49	0.51
Hubbard	sandy	Excessively drained	9,802.25	0.32
Waukon	fine-loamy	Well drained	9,547.10	0.32
Sverdrup	sandy	Well drained	8,885.89	0.29
Cathro	loamy	Very poorly drained	4,850.08	0.16

Naytahwaush	fine	Well drained	2,146.19	0.07
Itasca	coarse-loamy	Well drained	1,859.85	0.06
Sol	fine-loamy	Well drained	378.15	0.01
Total			**3,026,691.01**	**100.00**

Table 9. Saginaw Clay Lake and Till Plains

Soil series	Texture	Drainage	Acres	Percent
Parkhill	fine-loamy	Poorly drained	225,804.60	17.22
Londo	fine-loamy	Somewhat poorly drained	199,134.01	15.19
Lenawee	fine	Poorly drained	188,266.66	14.36
Granby	sandy	Poorly drained	93,606.60	7.14
Tappan	fine-loamy	Poorly drained	88,673.71	6.76
Shoals	fine-loamy	Somewhat poorly drained	67,476.68	5.15
Au Gres	sandy	Somewhat poorly drained	65,349.76	4.98
Iosco	sandy over loamy	Somewhat poorly drained	59,821.72	4.56
Essexville	sandy over loamy	Poorly drained	51,464.95	3.92
Conover	fine-loamy	Somewhat poorly drained	37,676.35	2.87
Latty	fine	Very poorly drained	36,642.82	2.79
Pipestone	sandy	Somewhat poorly drained	29,593.16	2.26
Urbanland	fine-loamy	Excessively drained	26,066.73	1.99
Pella	fine-silty	Poorly drained	24,641.68	1.88
Boyer	coarse-loamy	Well drained	24,587.88	1.88
Bach	coarse-silty	Poorly drained	14,566.80	1.11
Kingsville	not used	Poorly drained	13,652.28	1.04
Gilford	coarse-loamy	Very poorly drained	12,547.79	0.96
Wisner	fine-loamy	Poorly drained	10,551.58	0.80
Houghton	not used	Very poorly drained	10,243.86	0.78
Cathro	loamy	Very poorly drained	9,809.42	0.75
Marlette	fine-loamy	Well drained	8,193.62	0.62
Belleville	sandy over loamy	Poorly drained	4,693.28	0.36
Rubicon	sandy	Excessively drained	2,752.97	0.21
Nester	fine	Moderately well drained	2,692.92	0.21
Grayling	not used	Excessively drained	988.14	0.08
Pewamo	fine	Poorly drained	536.75	0.04
Perrinton	fine	Well drained	486.49	0.04
Miami	fine-loamy	Well drained	404.51	0.03
Guelph	fine-loamy	Moderately well drained	205.36	0.02
Spinks	sandy	Well drained	164.06	0.01
Total			**1,311,297.13**	**100.00**

Table 10. Seney Lake Plain

Soil series	Texture	Drainage	Acres	Percent
Dawson	sandy or sandy-skeletal	Very poorly drained	508,593.24	57.52
Lupton	not used	Very poorly drained	129,408.33	14.63
Kalkaska	sandy	Somewhat excessively drained	81,679.04	9.24
Rubicon	sandy	Excessively drained	60,024.28	6.79
Tawas	sandy or sandy-skeletal	Very poorly drained	44,657.81	5.05
Brimley	fine-loamy	Somewhat poorly drained	15,933.22	1.80
Sturgeon	coarse-silty over sandy	Somewhat poorly drained	15,553.86	1.76
Karlin	sandy	Somewhat excessively drained	8,193.50	0.93
Gogomain	coarse-loamy over clayey	Poorly drained	7,720.57	0.87
Blue Lake	sandy	Well drained	4,895.66	0.55
Pickford	fine	Poorly drained	3,502.83	0.40
Kiva	sandy	Well drained	1,063.24	0.12
Mancelona	sandy	Somewhat excessively drained	1,015.91	0.11
Longrie	coarse-loamy	Well drained	653.56	0.07
Cathro	loamy	Very poorly drained	589.35	0.07
Ontonagon	very-fine	Moderately well drained	393.39	0.04
Rousseau	sandy	Well drained	243.02	0.03
Onaway	fine-loamy	Moderately well drained	74.79	0.01
Water	sandy or sandy-skeletal	Very poorly drained	50.94	0.01
Carbondale	not used	Very poorly drained	0.14	< 0.01
Total			**884,246.69**	**100.00**

Table 11. Southern Green Bay Lobe

Soil series	Texture	Drainage	Acres	Percent
McHenry	fine-loamy	Well drained	755,472.05	27.14
Fox	fine-loamy over sandy	Well drained	555,666.26	19.96
Hochheim	fine-loamy	Well drained	521,451.28	18.73
Plano	fine-silty	Well drained	335,624.98	12.06
Lomira	fine-silty	Well drained	201,789.89	7.25
Houghton	not used	Very poorly drained	192,128.85	6.90
Pella	fine-silty	Poorly drained	88,140.27	3.17
Water	fine-loamy over sandy	Well drained	49,084.70	1.76
Kewaunee	fine	Well drained	38,710.22	1.39
Varna	fine	Well drained	31,415.32	1.13
Hebron	fine-loamy	Well drained	3,401.69	0.12
Flagg	fine-silty	Well drained	3,059.62	0.11
Zittau	clayey over sandy or sandy-skeletal	Somewhat poorly drained	3,026.67	0.11
Warsaw	fine-loamy over sandy	Well drained	2,290.19	0.08
NewGlarus	fine-silty over clayey	Well drained	1,008.01	0.04
Lapeer	coarse-loamy	Well drained	539.57	0.02
Basco	fine	Moderately well drained	209.44	0.01
Ogle	fine-silty	Well drained	156.53	0.01
Beecher	fine	Somewhat poorly drained	113.04	< 0.01
Dunbarton	clayey	Well drained	108.09	< 0.01
Gotham	not used	Well drained	28.67	< 0.01
Jasper	fine-loamy	Well drained	21.20	< 0.01
Hortonville	fine-loamy	Well drained	4.46	< 0.01
Total			**2,783,451.02**	**100.00**

Table 12. St. Louis Moraines

Soil series	Texture	Drainage	Acres	Percent
Itasca	coarse-loamy	Well drained	242,158.57	14.68
Warba	fine-loamy	Moderately well drained	236,241.35	14.32
Menahga	not used	Excessively drained	163,049.90	9.89
Nashwauk	fine-loamy	Well drained	128,743.91	7.81
Cushing	fine-loamy	Well drained	125,615.68	7.62
Duluth	fine-loamy	Well drained	122,834.21	7.45
Greenwood	not used	Very poorly drained	117,008.90	7.09
Cutaway	fine-loamy	Well drained	77,999.64	4.73
Ahmeek	coarse-loamy	Moderately well drained	71,845.45	4.36
Cromwell	sandy	Somewhat excessively drained	53,499.86	3.24
Brainerd	coarse-loamy	Moderately well drained	45,884.76	2.78
Hibbing	fine	Moderately well drained	41,363.53	2.51
Chetek	coarse-loamy	Somewhat excessively drained	27,831.16	1.69
Water			26,203.72	1.59
Indus	very-fine	Poorly drained	24,158.69	1.46
Suomi	fine	Moderately well drained	22,925.14	1.39
Mahtomedi	not used	Excessively drained	20,002.29	1.21
Zimmerman	not used	Excessively drained	19,066.13	1.16
Automba	coarse-loamy	Moderately well drained	16,531.92	1.00
Conic	coarse-loamy	Well drained	12,750.55	0.77
Rifle	not used	Very poorly drained	11,153.33	0.68
Rosy	coarse-loamy	Moderately well drained	9,418.55	0.57
Mora	coarse-loamy	Moderately well drained	5,577.16	0.34
Spooner	fine-silty	Poorly drained	5,204.86	0.32
Alstad	fine-loamy	Somewhat poorly drained	4,730.20	0.29
Omega	sandy	Somewhat excessively drained	4,405.12	0.27
Pengilly	coarse-loamy	Poorly drained	4,400.77	0.27
Nemadji	sandy	Somewhat poorly drained	4,155.36	0.25
Redby	not used	Somewhat poorly drained	2,882.43	0.17
Loxley	not used	Very poorly drained	880.48	0.05
Wawina	coarse-loamy	Well drained	370.47	0.02
Tonkey	coarse-loamy	Poorly drained	229.94	0.01
Meehan	not used	Somewhat poorly drained	221.35	0.01
Total			**1,649,345.38**	**100.00**

Table 13. Superior-Ashland Clay Plain

Soil series	Texture	Drainage	Acres	Percent
Ontonagon	coarse-loamy	Moderately well drained	518,034.66	39.86
Hibbing	coarse-loamy	Moderately well drained	282,230.44	21.72
Watton	fine-loamy	Well drained	258,955.27	19.93
Sayner	sandy	Excessively drained	49,134.35	3.78
Gogebic	coarse-loamy	Moderately well drained	35,261.25	2.71
Kinross	sandy	Somewhat excessively drained	28,893.83	2.22
Nemadji	coarse-loamy	Moderately well drained	23,036.36	1.77
Rubicon	sandy	Excessively drained	20,259.86	1.56
Graveraet	coarse-loamy	Moderately well drained	18,601.77	1.43
Munising	coarse-loamy	Moderately well drained	14,087.33	1.08
Omega	coarse-loamy	Moderately well drained	12,331.89	0.95
Spooner	sandy	Excessively drained	11,832.85	0.91
Sturgeon	coarse-silty over sandy	Somewhat poorly drained	7,979.14	0.61
Ahmeek	coarse-loamy	Moderately well drained	7,120.96	0.55
Champion	coarse-loamy	Well drained	5,058.36	0.39
Duluth	coarse-loamy	Well drained	2,757.86	0.21
Kalkaska	sandy	Somewhat excessively drained	2,356.90	0.18
Rock outcrop	coarse-loamy	Moderately well drained	549.38	0.04
Au Gres	sandy	Somewhat poorly drained	492.20	0.04
Finland	coarse-loamy	Well drained	319.86	0.02
Conic	coarse-loamy	Well drained	193.82	0.01
Bohemian	fine-loamy	Moderately well drained	14.03	< 0.01
Sartell	sandy	Excessively drained	5.37	< 0.01
Total			**1,299,507.75**	**100.00**

Table 14. Toimi Uplands

Soil series	Texture	Drainage	Acres	Percent
Greenwood	not used	Very poorly drained	548,052.62	36.17
Spooner	fine-silty	Poorly drained	196,850.19	12.99
Duluth	fine-loamy	Well drained	154,220.57	10.18
Hibbing	fine	Moderately well drained	151,018.91	9.97
Redby	not used	Somewhat poorly drained	131,785.32	8.70
Zimmerman	not used	Excessively drained	63,208.85	4.17
Cushing	fine-loamy	Well drained	53,056.81	3.50
Pengilly	coarse-loamy	Poorly drained	51,812.09	3.42
Cloquet	coarse-loamy over sandy	Somewhat excessively drained	22,610.27	1.49
Itasca	coarse-loamy	Well drained	19,880.30	1.31
Tonkey	coarse-loamy	Poorly drained	18,116.71	1.20
Meehan	not used	Somewhat poorly drained	16,355.29	1.08
Wawina	coarse-loamy	Well drained	15,814.90	1.04
Nemadji	sandy	Somewhat poorly drained	12,934.24	0.85
Warba	fine-loamy	Moderately well drained	11,563.80	0.76
Sartell	not used	Excessively drained	11,397.12	0.75
Menahga	not used	Excessively drained	8,601.29	0.57
Loxley	not used	Very poorly drained	7,092.01	0.47
Conic	coarse-loamy	Well drained	5,439.31	0.36
Cutaway	fine-loamy	Well drained	5,033.61	0.33
Toimi	coarse-loamy	Moderately well drained	4,961.28	0.33
Rosy	coarse-loamy	Moderately well drained	3,627.61	0.24
Mahtomedi	not used	Excessively drained	660.56	0.04
Ahmeek	coarse-loamy	Moderately well drained	654.80	0.04
Water			137.45	0.01
Omega	sandy	Somewhat excessively drained	122.72	0.01
Nashwauk	fine-loamy	Well drained	57.23	< 0.01
Total			**1,515,065.88**	**100.00**

Table 15. Western Paleozoic Plateau

Soil series	Texture	Drainage	Acres	Percent
Nappanee	fine	Somewhat poorly drained	1,287,972.82	36.81
Latty	fine	Very poorly drained	297,467.77	8.50
Pewamo	fine	Poorly drained	296,664.75	8.48
Urbanland	fine-silty	Poorly drained	250,210.53	7.15
Lenawee	fine	Very poorly drained	208,876.99	5.97
Ottokee	fine	Somewhat poorly drained	189,082.14	5.40
Toledo	fine-silty	Poorly drained	158,045.76	4.52
Millgrove	fine-loamy	Well drained	151,677.27	4.33
Kibbie	fine-loamy over sandy	Somewhat poorly drained	121,164.86	3.46
Conover	not used	Excessively drained	83,708.80	2.39
Gilford	coarse-loamy	Very poorly drained	64,075.39	1.83
Oakville	fine	Somewhat poorly drained	63,857.01	1.82
Roselms	fine	Poorly drained	59,635.97	1.70
Wasepi	fine-silty	Poorly drained	51,741.14	1.48
Colwood	not used	Excessively drained	47,132.77	1.35
Belleville	sandy over loamy	Poorly drained	36,914.33	1.05
Glynwood	fine	Moderately well drained	31,761.11	0.91
Spinks	fine-silty	Poorly drained	28,288.41	0.81
Sawmill	fine-silty	Poorly drained	16,461.78	0.47
Shoals	fine-silty	Poorly drained	11,600.76	0.33
Morley	fine	Very poorly drained	10,184.44	0.29
Brady	coarse-loamy	Somewhat poorly drained	8,409.94	0.24
Homer	fine-loamy over sandy	Somewhat poorly drained	5,740.45	0.16
Bach	coarse-silty	Poorly drained	5,421.91	0.15
Castalia	loamy-skeletal	Well drained	5,013.27	0.14
Millsdale	fine-loamy	Well drained	2,763.80	0.08
Montgomery	fine	Very poorly drained	2,164.52	0.06
Arkport	coarse-loamy	Well drained	1,795.98	0.05
Martinsville	fine-loamy	Well drained	1,024.54	0.03
Coloma	not used	Excessively drained	403.57	0.01
Total			**3,499,262.78**	**100.00**

Appendix 7. Land cover (NLCD 2001) by refuge, listed in ranked order by area. Refuges are listed alphabetically.

Table 1. Cedar Point NWR

Land cover	Acres	Percent
Emergent Herbaceous Wetlands	1,713.16	65.96
Open Water	849.90	32.72
Developed, Open Space	13.13	0.51
Developed, Low Intensity	11.13	0.43
Barren Land	9.61	0.37
Herbaceous	0.44	0.02
Total	**2,597.38**	**100.00**

Table 2. Crane Meadows NWR

Land cover	Acres	Percent
Emergent Herbaceous Wetlands	621.96	39.66
Cultivated Crops	326.56	20.82
Deciduous Forest	295.56	18.85
Hay/Pasture	171.82	10.96
Herbaceous	90.88	5.79
Developed, Open Space	26.68	1.70
Open Water	17.17	1.09
Evergreen Forest	6.66	0.42
Woody Wetlands	5.23	0.33
Shrub/Scrub	4.10	0.26
Developed, Low Intensity	1.78	0.11
Total	**1,568.38**	**100.00**

Table 3. Detroit River IWR

Land cover	Acres	Percent
Open Water	761.95	52.75
Deciduous Forest	169.90	11.76
Cultivated Crops	165.58	11.46
Emergent Herbaceous Wetlands	86.96	6.02
Woody Wetlands	84.40	5.84
Developed, Low Intensity	50.71	3.51
Herbaceous	48.55	3.36
Barren Land	45.33	3.14
Developed, Open Space	17.06	1.18
Hay/Pasture	6.31	0.44
Developed, Medium Intensity	5.93	0.41
Shrub/Scrub	0.99	0.07
Developed, High Intensity	0.79	0.05
Total	**1,444.47**	**100.00**

Table 4. Green Bay NWR

Land cover	Acres	Percent
Deciduous Forest	219.63	68.53
Barren Land	63.30	19.75
Shrub/Scrub	22.06	6.88
Developed, Open Space	5.83	1.82
Herbaceous	4.09	1.28
Open Water	3.21	1.00
Emergent Herbaceous Wetlands	1.18	0.37
Mixed Forest	1.18	0.37
Total	**320.48**	**100.00**

Table 5. Horicon NWR

Land cover	Acres	Percent
Emergent Herbaceous Wetlands	13,076.46	59.85
Open Water	5,285.69	24.19
Cultivatred Crops	2,194.16	10.04
Woody Wetlands	671.42	3.07
Deciduous Forest	247.87	1.13
Developed, Open Space	226.05	1.03
Developed, Low Intensity	52.23	0.24
Hay/Pasture	36.47	0.17
Shrub/Scrub	33.44	0.15
Developed, Medium Intensity	18.19	0.08
Herbaceous	8.03	0.04
Total	**21,850.02**	**100.00**

Table 6. Kirtland's Warbler WMA

Land cover	Acres	Percent
Evergreen Forest	2,532.50	38.43
Herbaceous	1,643.48	24.94
Shrub/Scrub	1,045.36	15.86
Developed, Open Space	426.26	6.47
Woody Wetlands	414.72	6.29
Mixed Forest	232.56	3.53
Deciduous Forest	127.22	1.93
Emergent Herbaceous Wetlands	90.52	1.37
Developed, Low Intensity	51.79	0.79
Open Water	23.08	0.35
Barren Land	0.71	0.01
Developed, Medium Intensity	0.59	0.01
Cultivated Crops	0.43	0.01
Total	**6,589.21**	**100.00**

Table 7. Necedah NWR

Land cover	Acres	Percent
Deciduous Forest	15,371.12	35.07
Woody Wetlands	7,833.03	17.87
Emergent Herbaceous Wetlands	7,328.76	16.72
Herbaceous	4,068.81	9.28
Shurb/Scrub	2,617.95	5.97
Open Water	2,281.56	5.21
Developed, Open Space	1,433.11	3.27
Mixed Forest	983.31	2.24
Cultivated Crops	960.70	2.19
Evergreen Forest	944.25	2.15
Developed, Low Intensity	6.06	0.01
Total	**43,828.65**	**100.00**

Table 8. Ottawa NWR

Land cover	Acres	Percent
Emergent Herbaceous Wetlands	3,534.64	59.58
Open Water	1,246.15	21.00
Cultivated Crops	876.52	14.77
Developed, Open Space	139.16	2.35
Developed, Low Intensity	113.60	1.91
Developed, Medium Intensity	9.02	0.15
Herbaceous	7.08	0.12
Deciduous Forest	4.36	0.07
Barren Land	2.44	0.04
Total	**5,932.98**	**100.00**

Table 9. Rice Lake NWR

Land cover	Acres	Percent
Deciduous Forest	8,729.78	43.36
Emergent Herbaceous Wetlands	4,974.06	24.71
Open Water	3,772.87	18.74
Woody Wetlands	1,066.08	5.30
Herbaceous	582.83	2.90
Hay/Pasture	460.18	2.29
Developed, Open Space	272.96	1.36
Evergreen Forest	214.61	1.07
Cultivated Crops	38.53	0.19
Shurb/Scrub	16.82	0.08
Mixed Forest	2.97	0.01
Developed, Low Intensity	0.39	< 0.01
Total	**20,132.07**	**100.00**

Table 10. Seney NWR

Land cover	Acres	Percent
Woody Wetlands	43,075.16	45.13
Emergent Herbaceous Wetlands	34,524.31	36.17
Evergreen Forest	7,163.78	7.51
Open Water	4,403.96	4.61
Deciduous Forest	2,550.71	2.67
Herbaceous	1,667.03	1.75
Developed, Open Space	1,142.93	1.20
Mixed Forest	602.64	0.63
Developed, Low Intensity	130.74	0.14
Cultivatred Crops	101.56	0.11
Shrub/Scrub	60.58	0.06
Developed, Medium Intensity	15.69	0.02
Developed, High Intensity	1.07	< 0.01
Barren Land	1.04	< 0.01
Total	**95,441.19**	**100.00**

Table 11. Sherburne NWR

Land cover	Acres	Percent
Emergent Herbaceous Wetlands	8,751.79	28.56
Deciduous Forest	7,860.53	25.65
Cultivated Crops	6,863.22	22.40
Herbaceous	1,998.39	6.52
Open Water	1,857.18	6.06
Hay/Pasture	1,822.94	5.95
Evergreen Forest	565.66	1.85
Developed, Open Space	487.16	1.59
Shrub, Scrub	410.66	1.34
Woody Wetlands	15.45	0.05
Mixed Forest	10.42	0.03
Developed, Low Intensity	0.99	< 0.01
Total	**30,644.39**	**100.00**

Table 12. Shiawassee NWR

Land cover	Acres	Percent
Woody Wetlands	2,905.77	30.44
Deciduous Forest	2,099.13	21.99
Cultivated Crops	2,076.87	21.76
Open Water	919.77	9.63
Emergent Herbaceous Wetlands	531.49	5.57
Developed, Open Space	354.77	3.72
Herbaceous	191.34	2.00
Hay/Pasture	188.05	1.97
Developed, Low Intensity	109.38	1.15
Barren Land	54.56	0.57
Evergreen Forest	46.35	0.49
Mixed Forest	40.01	0.42
Shrub/Scrub	24.94	0.26
Developed, Medium Intensity	2.54	0.03
Developed, High Intensity	1.18	0.01
Total	**9,546.13**	**100.00**

Table 13. Tamarac NWR

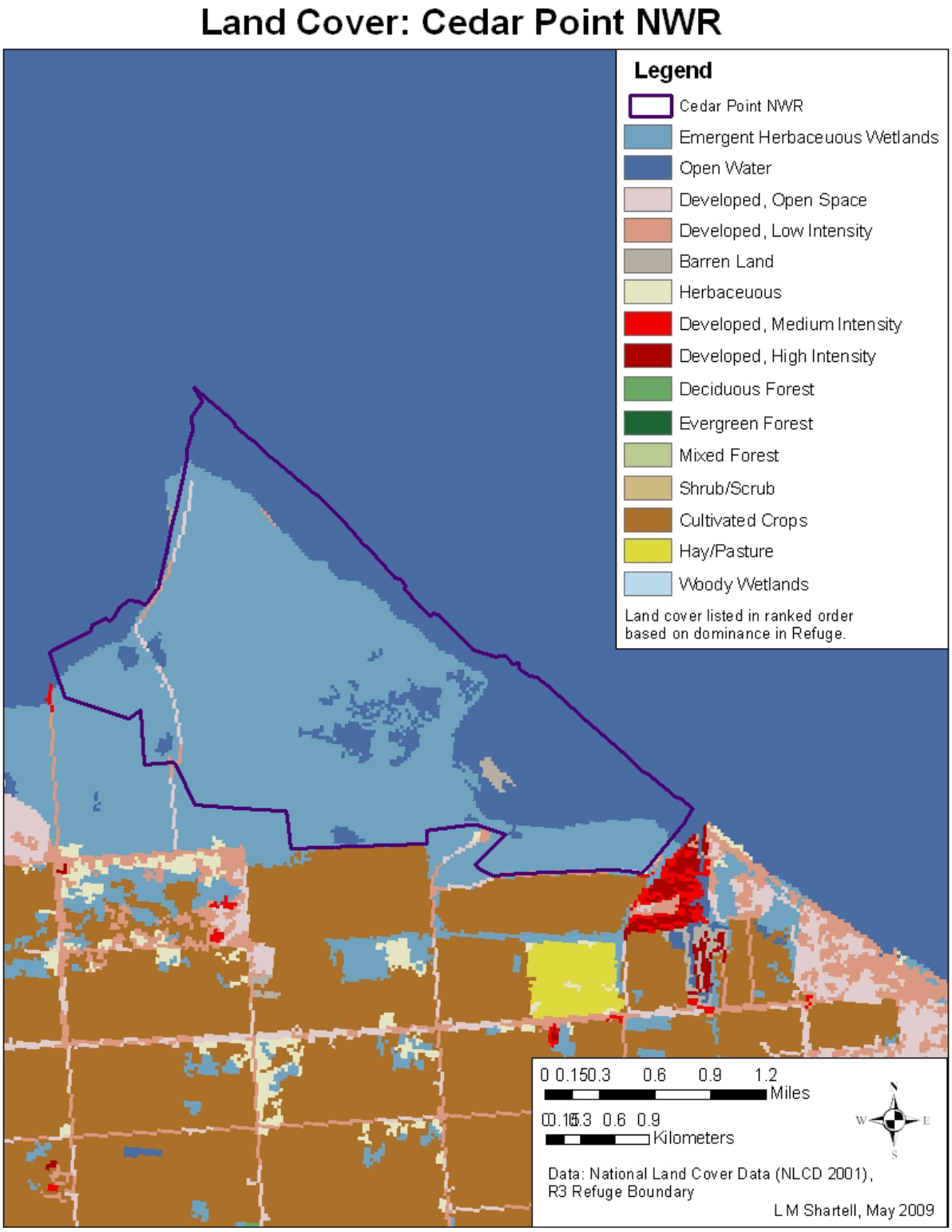
Land cover	Acres	Percent
Deciduous Forest	24,342.85	55.45
Open Water	6,940.54	15.81
Emergent Herbaceous Wetlands	4,989.79	11.37
Evergreen Forest	3,800.74	8.66
Shrub/Scrub	1,187.60	2.71
Herbaceous	864.60	1.97
Woody Wetlands	849.14	1.93
Developed, Open Space	540.39	1.23
Hay/Pasture	267.46	0.61
Developed, Low Intensity	54.56	0.12
Cultivated Crops	45.43	0.10
Mixed Forest	12.55	0.03
Barren Land	2.37	0.01
Developed, Medium Intensity	2.08	< 0.01
Total	**43,900.11**	**100.00**

Table 14. Whittlesey Creek NWR

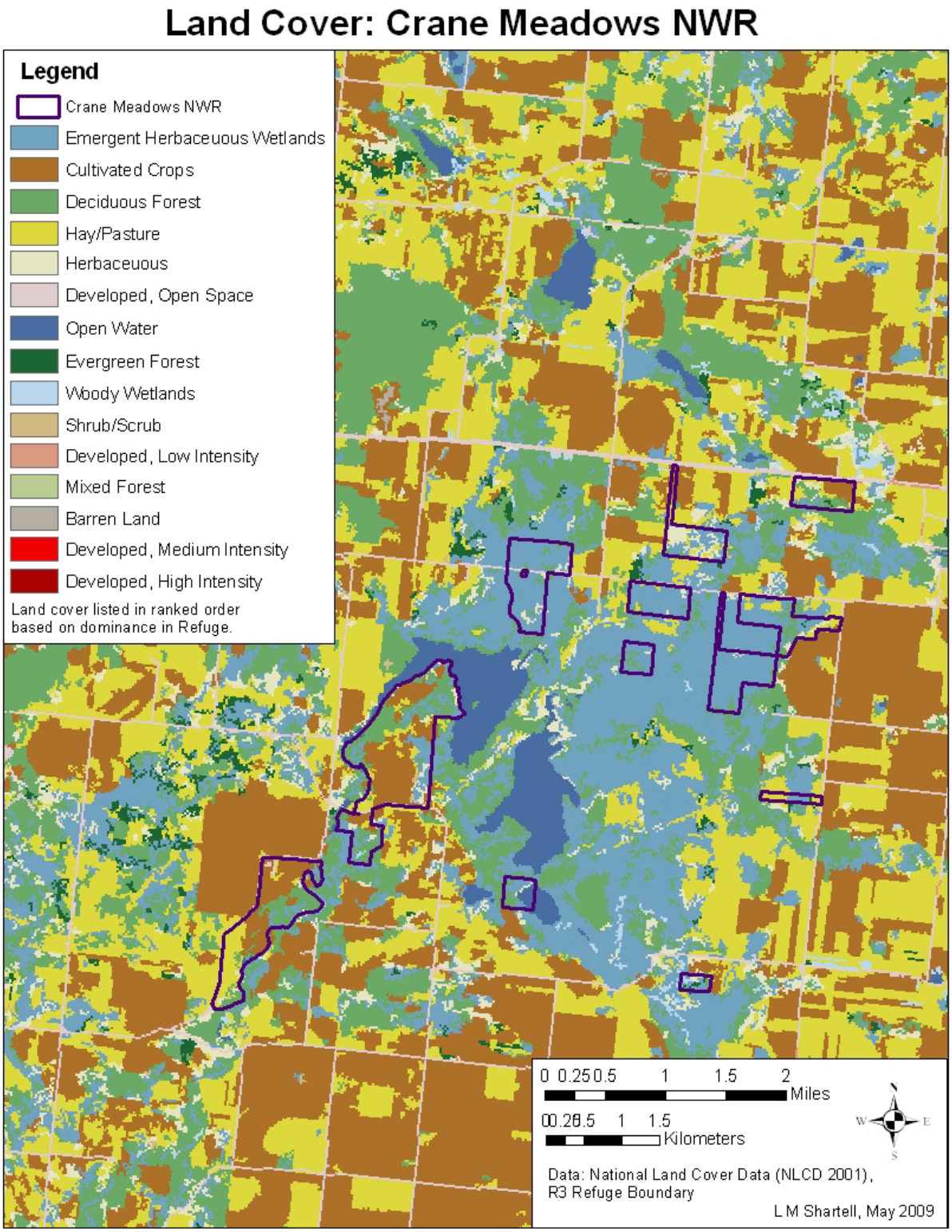
Land cover	Acres	Percent
Emergent Herbaceous Wetlands	177.46	61.43
Deciduous Forest	33.97	11.76
Evergreen Forest	31.85	11.03
Hay/Pasture	28.96	10.02
Developed, Open Space	13.99	4.84
Woody Wetlands	1.31	0.45
Developed, Low Intensity	0.81	0.28
Open Water	0.52	0.18
Total	**288.87**	**100.00**

Appendix 8. Maps of land cover (NLCD 2001) by refuge. Refuges are listed alphabetically.

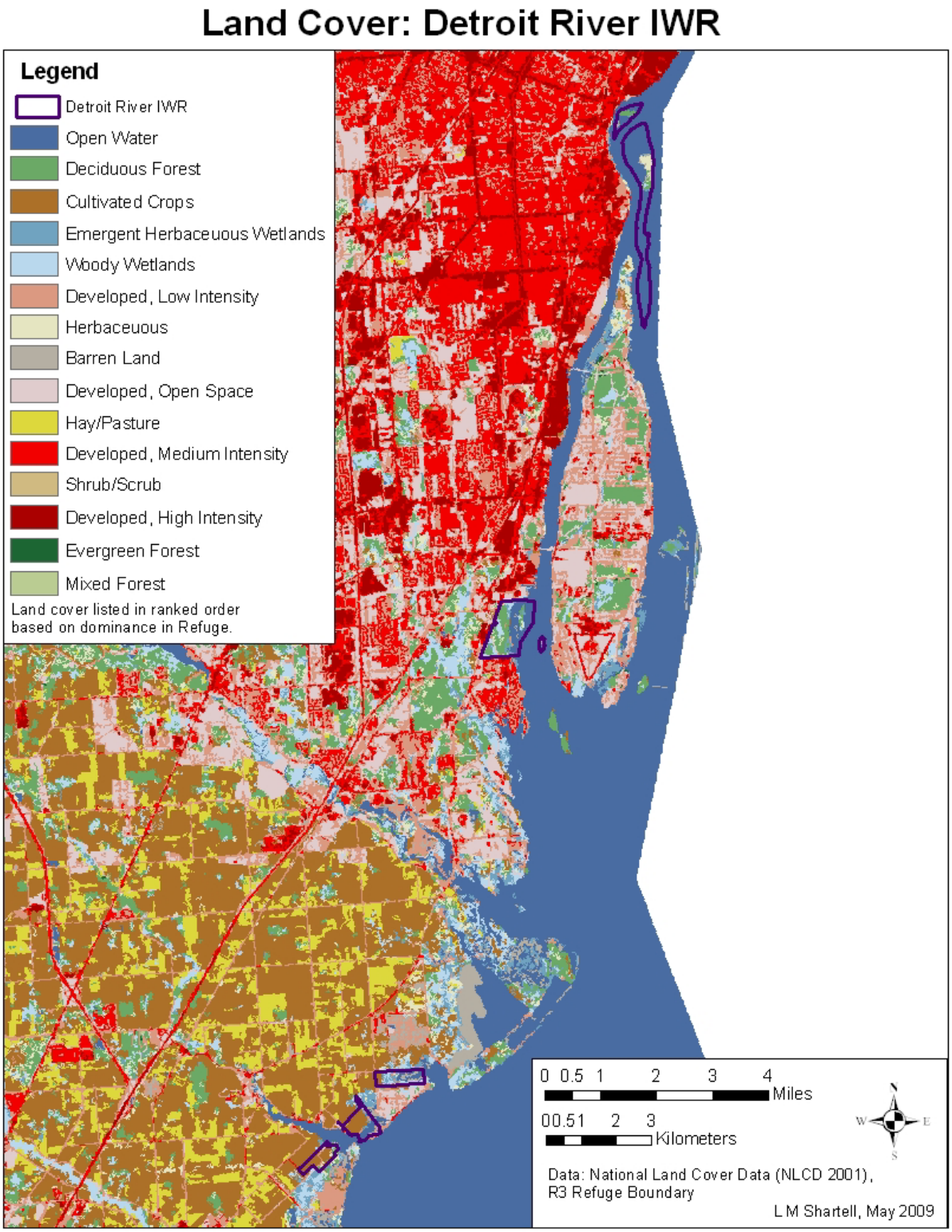
Map 1.



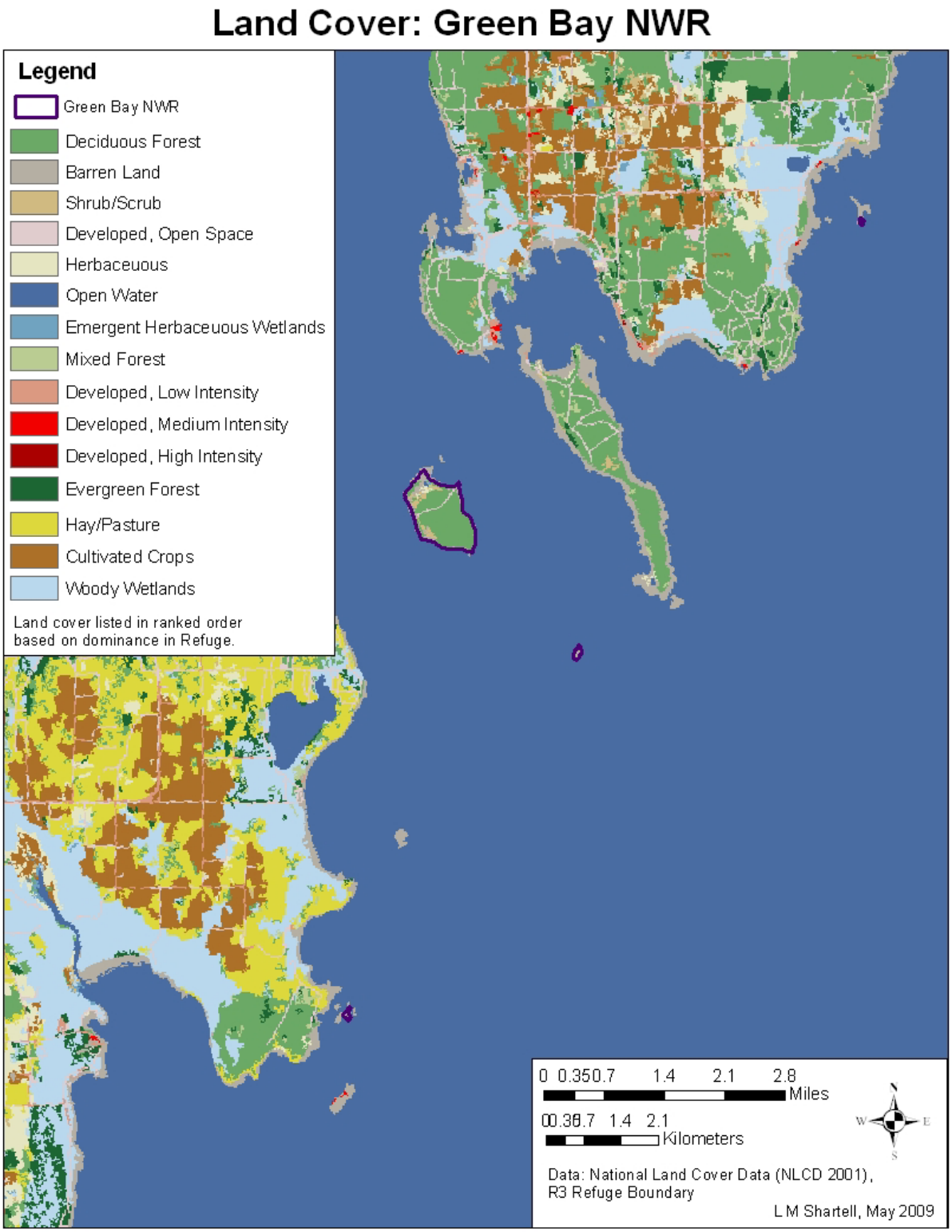
Map 2.


Land Cover: Crane Meadows NWR
Legend
Crane Meadows NWR
Emergent Herbaceuous Wetlands
Cultivated Crops
Deciduous Forest
Hay/Pasture
Herbaceuous
Developed, Open Space
Open Water
Evergreen Forest
Woody Wetlands
Shrub/Scrub
Developed, Low Intensity
Mixed Forest
Barren Land
Developed, Medium Intensity
Developed, High Intensity
Land cover listed in ranked order based on dominance in Refuge.
0 0.25 0.5 1 1.5 2
Miles
0 0.25 0.5 1 1.5
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), R3 Refuge Boundary
L M Shartell, May 2009

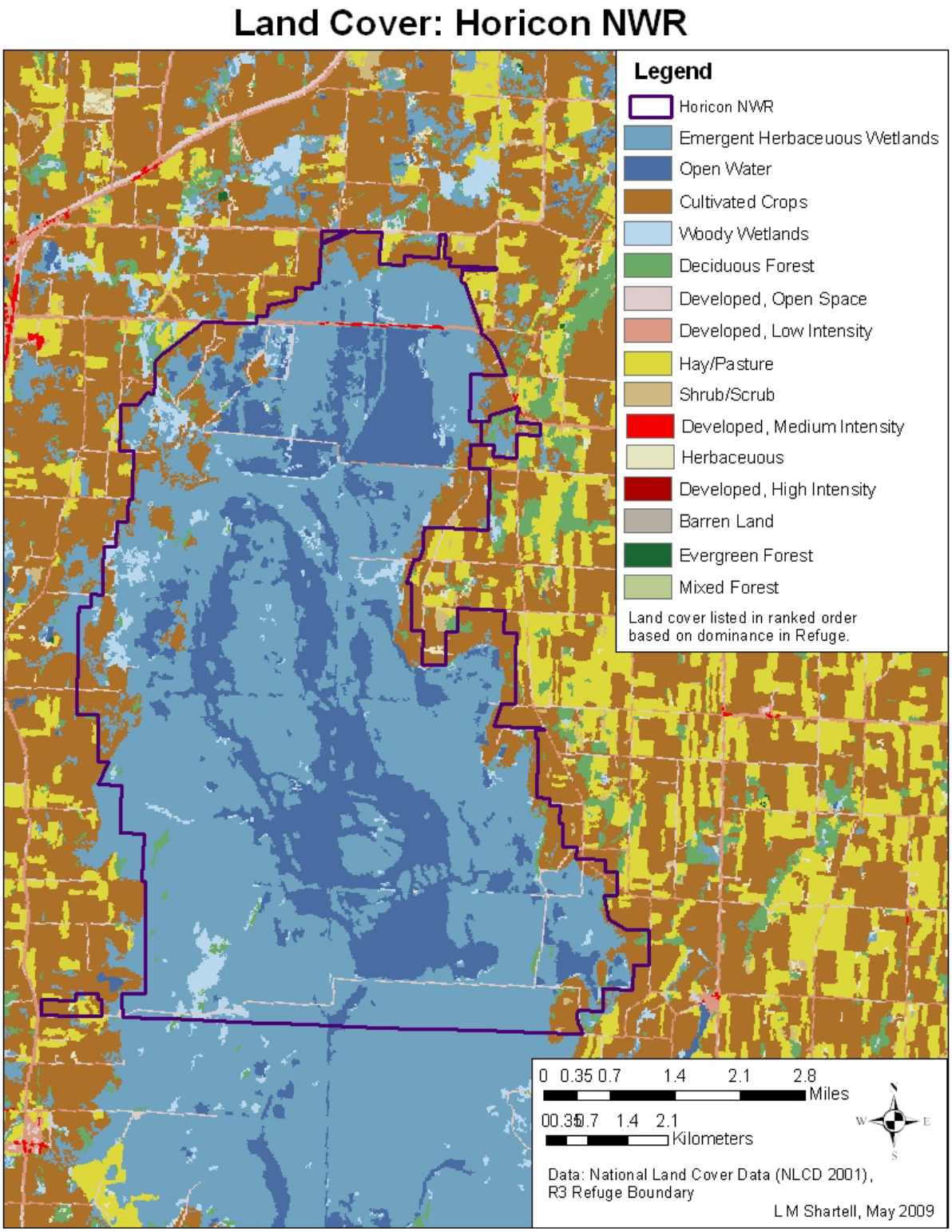
Map 3.


Land Cover: Detroit River IWR
Legend
Detroit River IWR
Open Water
Deciduous Forest
Cultivated Crops
Emergent Herbaceuous Wetlands
Woody Wetlands
Developed, Low Intensity
Herbaceuous
Barren Land
Developed, Open Space
Hay/Pasture
Developed, Medium Intensity
Shrub/Scrub
Developed, High Intensity
Evergreen Forest
Mixed Forest
Land cover listed in ranked order based on dominance in Refuge.
0 0.5 1 2 3 4
Miles
00.51 2 3
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), R3 Refuge Boundary
L M Shartell, May 2009

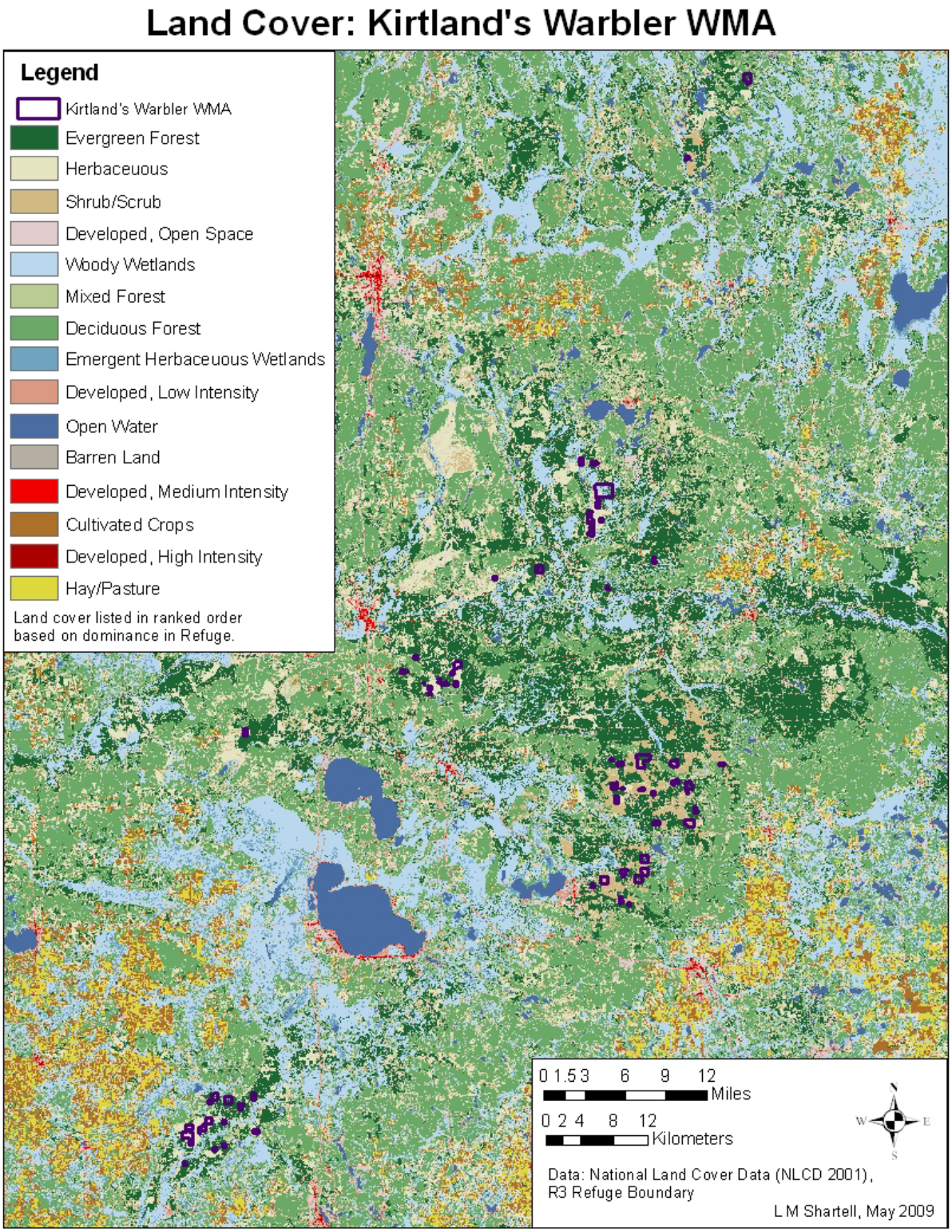
Map 4.


Land Cover: Green Bay NWR
Legend
Green Bay NWR
Deciduous Forest
Barren Land
Shrub/Scrub
Developed, Open Space
Herbaceuous
Open Water
Emergent Herbaceuous Wetlands
Mixed Forest
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Evergreen Forest
Hay/Pasture
Cultivated Crops
Woody Wetlands
Land cover listed in ranked order based on dominance in Refuge.
0 0.350.7 1.4 2.1 2.8
Miles
00.36.7 1.4 2.1
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), R3 Refuge Boundary
L M Shartell, May 2009

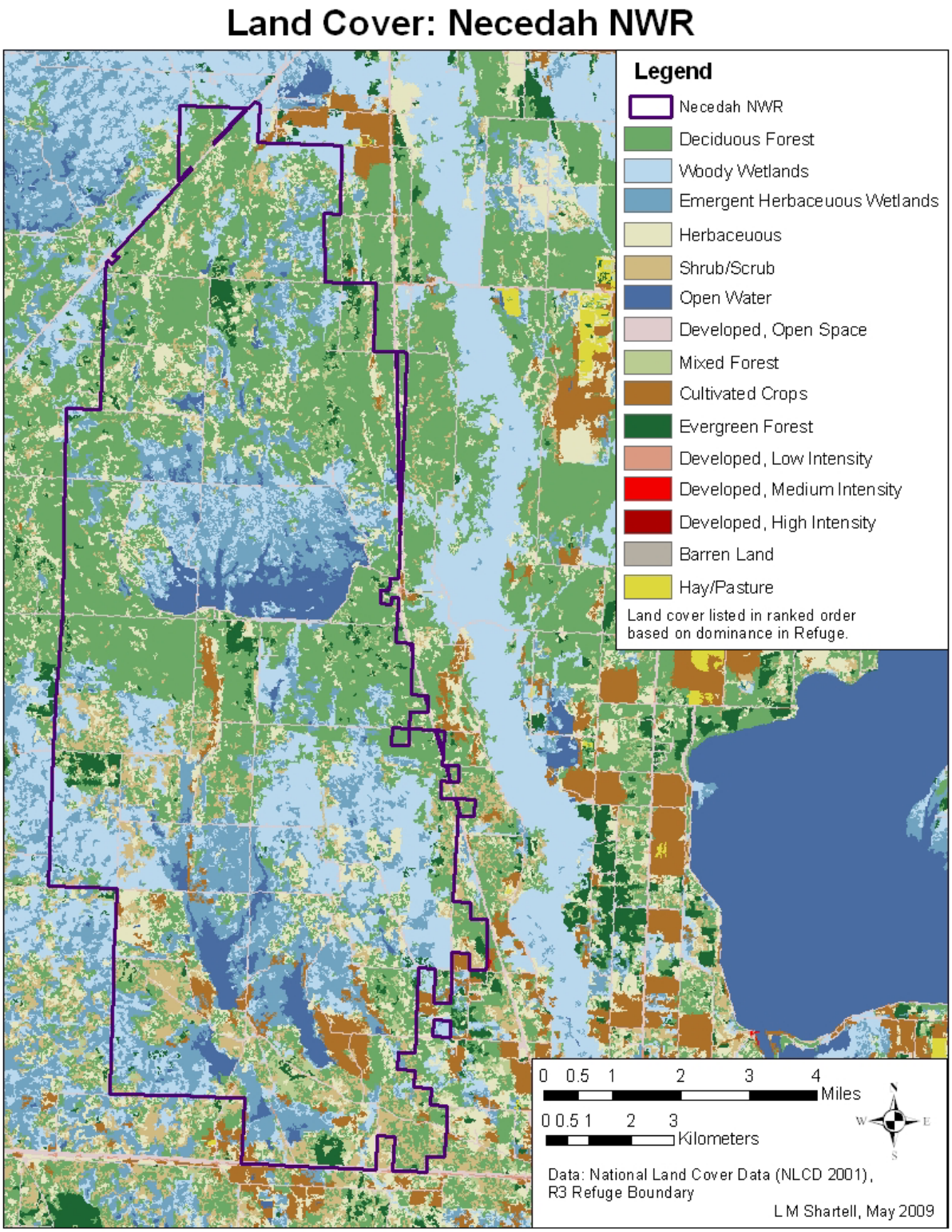
Map 5.


Land Cover: Horicon NWR
Legend
Horicon NWR
Emergent Herbaceuous Wetlands
Open Water
Cultivated Crops
Woody Wetlands
Deciduous Forest
Developed, Open Space
Developed, Low Intensity
Hay/Pasture
Shrub/Scrub
Developed, Medium Intensity
Herbaceuous
Developed, High Intensity
Barren Land
Evergreen Forest
Mixed Forest
Land cover listed in ranked order based on dominance in Refuge.
0 0.35 0.7 1.4 2.1 2.8
Miles
0 0.35 0.7 1.4 2.1
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), R3 Refuge Boundary
L M Shartell, May 2009

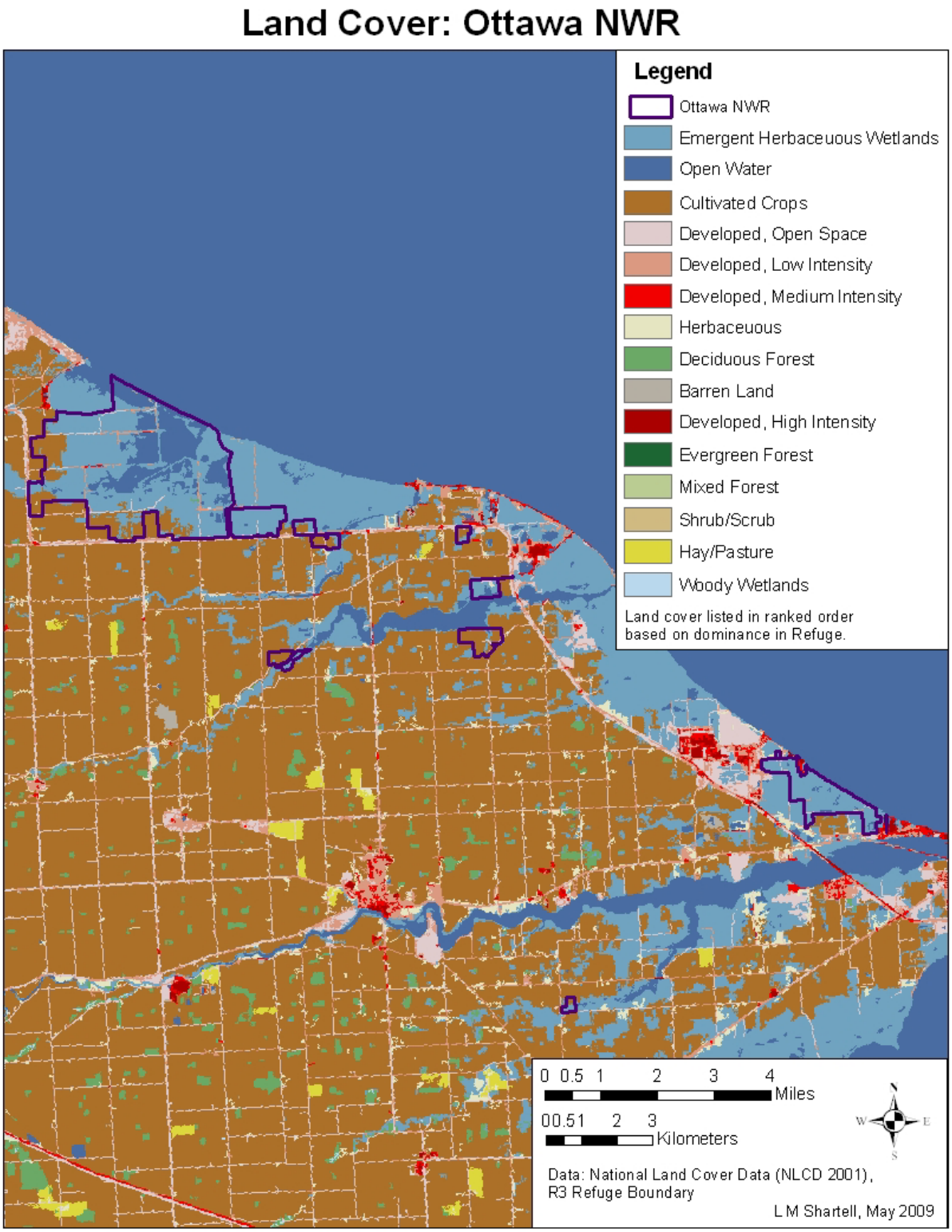
Map 6.


Land Cover: Kirtland's Warbler WMA
Legend
Kirtland's Warbler WMA
Evergreen Forest
Herbaceuous
Shrub/Scrub
Developed, Open Space
Woody Wetlands
Mixed Forest
Deciduous Forest
Emergent Herbaceuous Wetlands
Developed, Low Intensity
Open Water
Barren Land
Developed, Medium Intensity
Cultivated Crops
Developed, High Intensity
Hay/Pasture
Land cover listed in ranked order based on dominance in Refuge.
0 1.5 3 6 9 12
Miles
0 2 4 8 12
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), R3 Refuge Boundary
L M Shartell, May 2009

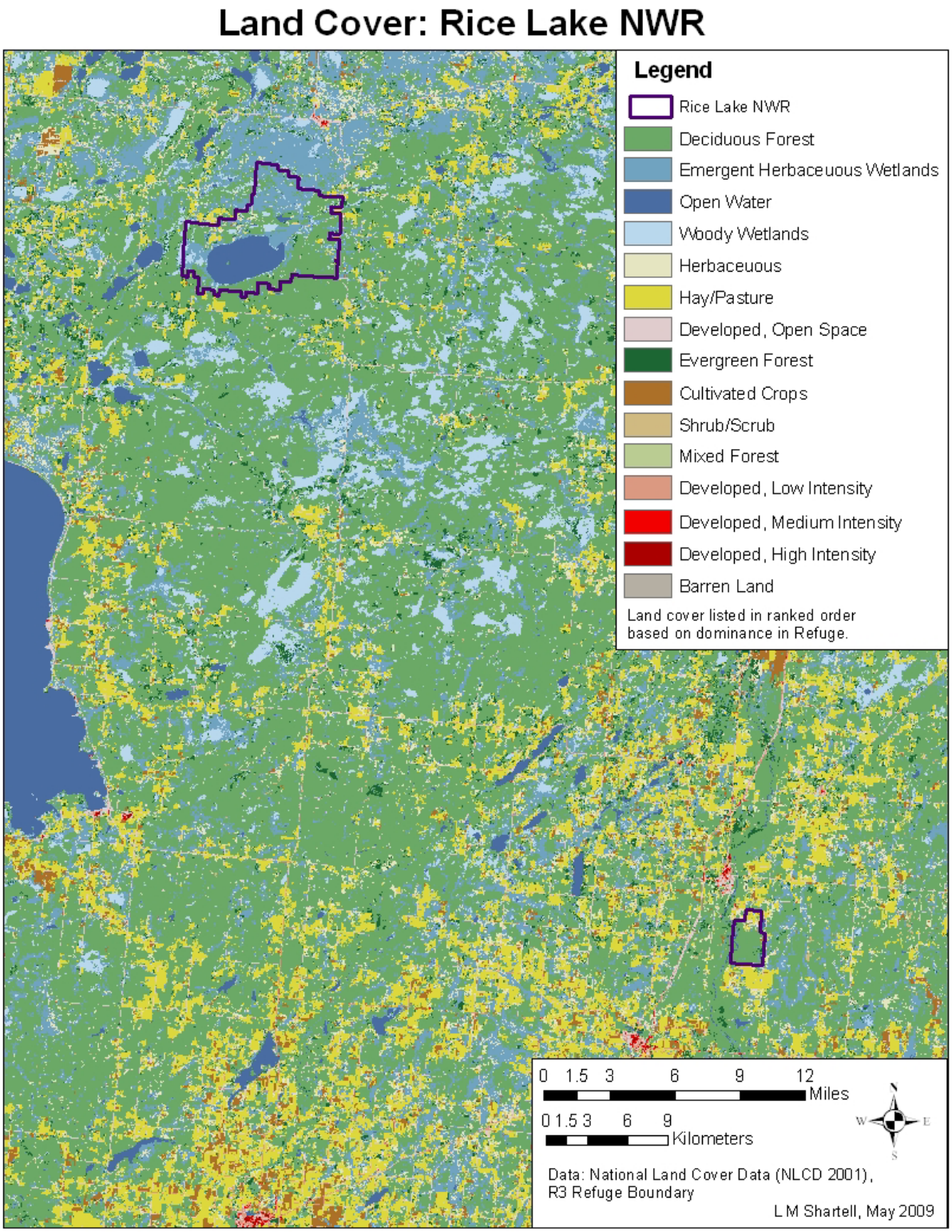
Map 7.


Land Cover: Necedah NWR
Legend
Necedah NWR
Deciduous Forest
Woody Wetlands
Emergent Herbaceuous Wetlands
Herbaceuous
Shrub/Scrub
Open Water
Developed, Open Space
Mixed Forest
Cultivated Crops
Evergreen Forest
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Hay/Pasture
Land cover listed in ranked order based on dominance in Refuge.
0 0.5 1 2 3 4
Miles
0 0.5 1 2 3
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), R3 Refuge Boundary
L M Shartell, May 2009

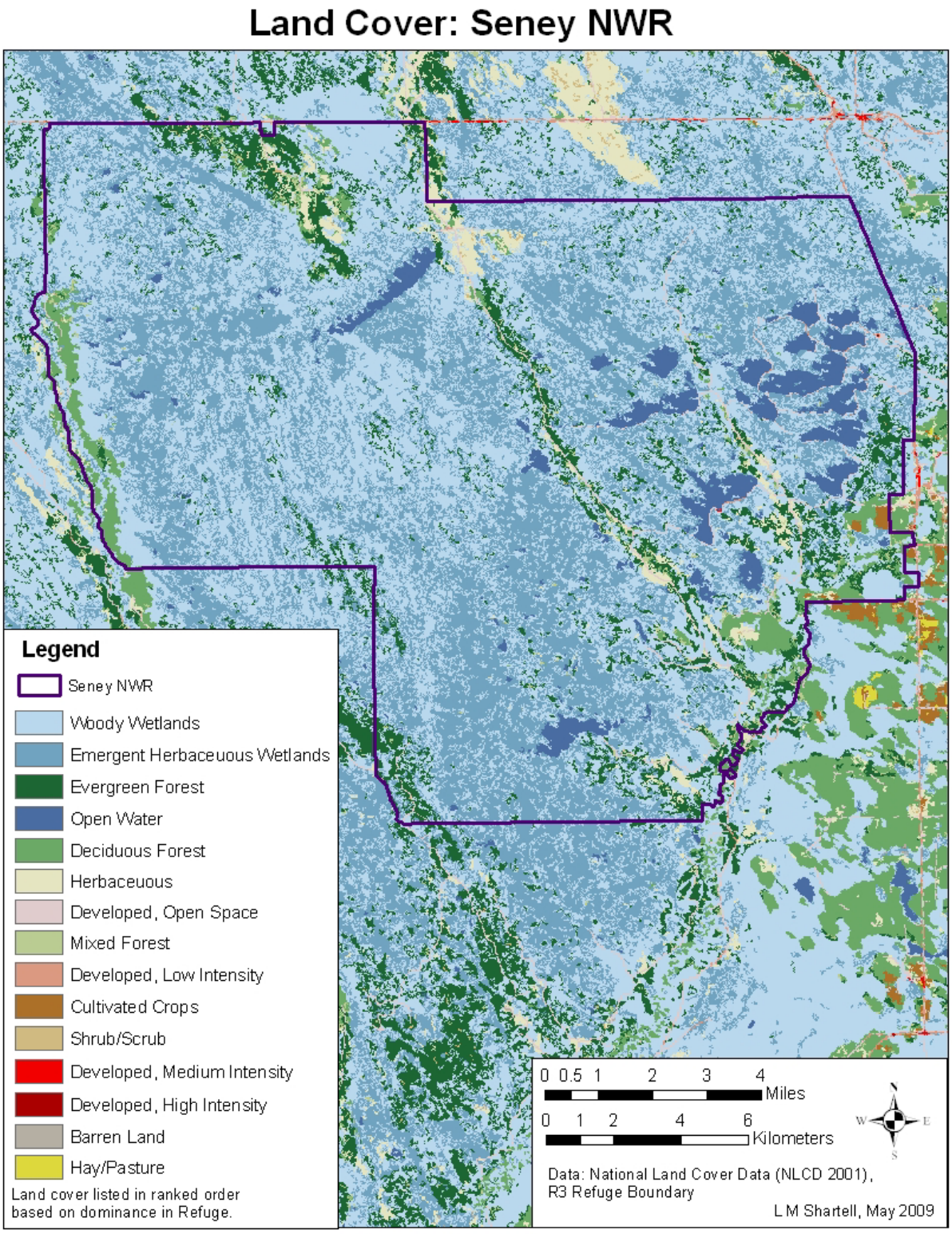
Map 8.


Land Cover: Ottawa NWR
Legend
Ottawa NWR
Emergent Herbaceuous Wetlands
Open Water
Cultivated Crops
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Herbaceuous
Deciduous Forest
Barren Land
Developed, High Intensity
Evergreen Forest
Mixed Forest
Shrub/Scrub
Hay/Pasture
Woody Wetlands
Land cover listed in ranked order based on dominance in Refuge.
0 0.5 1 2 3 4
Miles
00.51 2 3
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), R3 Refuge Boundary
L M Shartell, May 2009

Map 9.

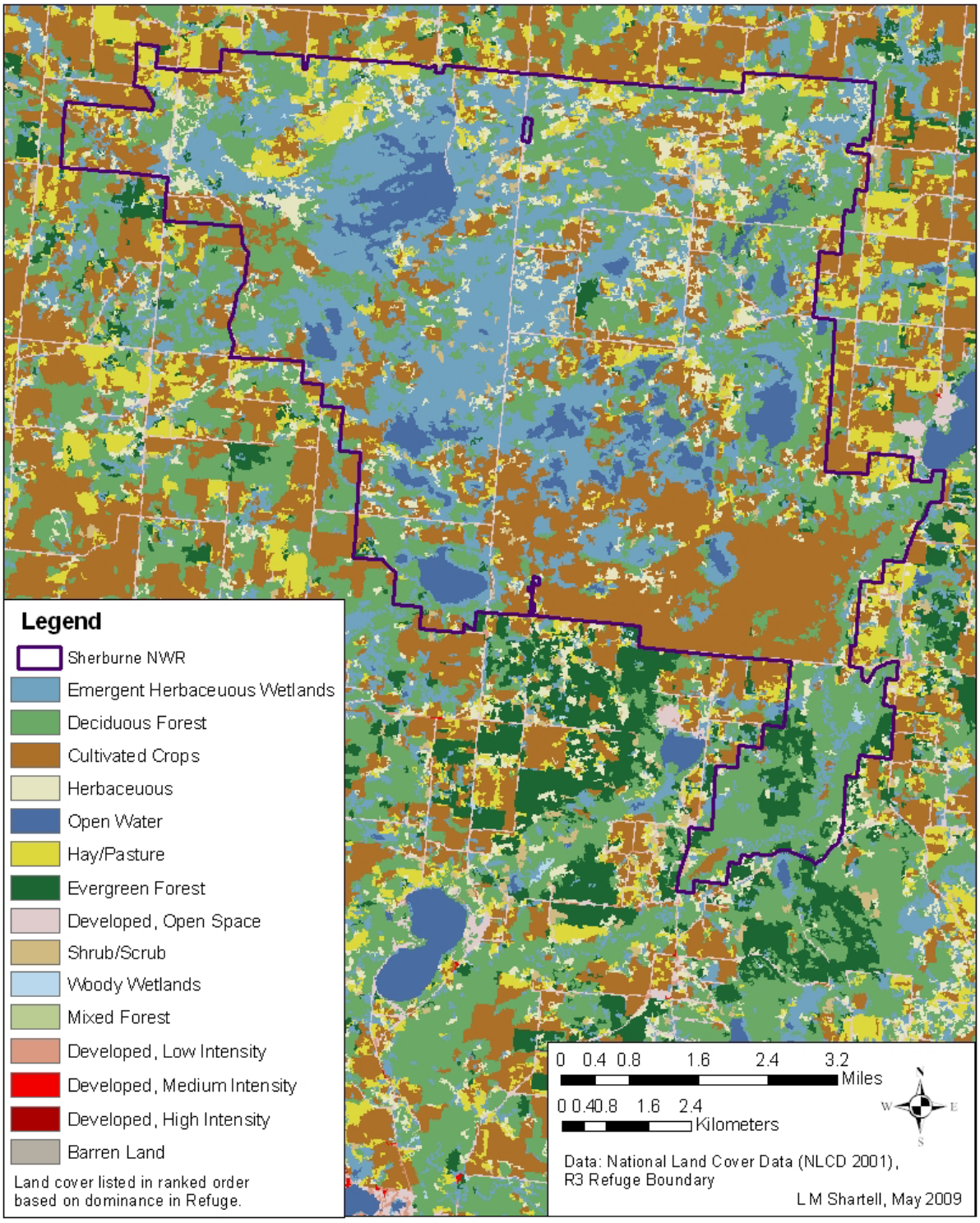

Land Cover: Rice Lake NWR
Legend
Rice Lake NWR
Deciduous Forest
Emergent Herbaceuous Wetlands
Open Water
Woody Wetlands
Herbaceuous
Hay/Pasture
Developed, Open Space
Evergreen Forest
Cultivated Crops
Shrub/Scrub
Mixed Forest
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Land cover listed in ranked order based on dominance in Refuge.
0 1.5 3 6 9 12
Miles
0 1.5 3 6 9
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), R3 Refuge Boundary
L M Shartell, May 2009

Map 10. Seney NWR

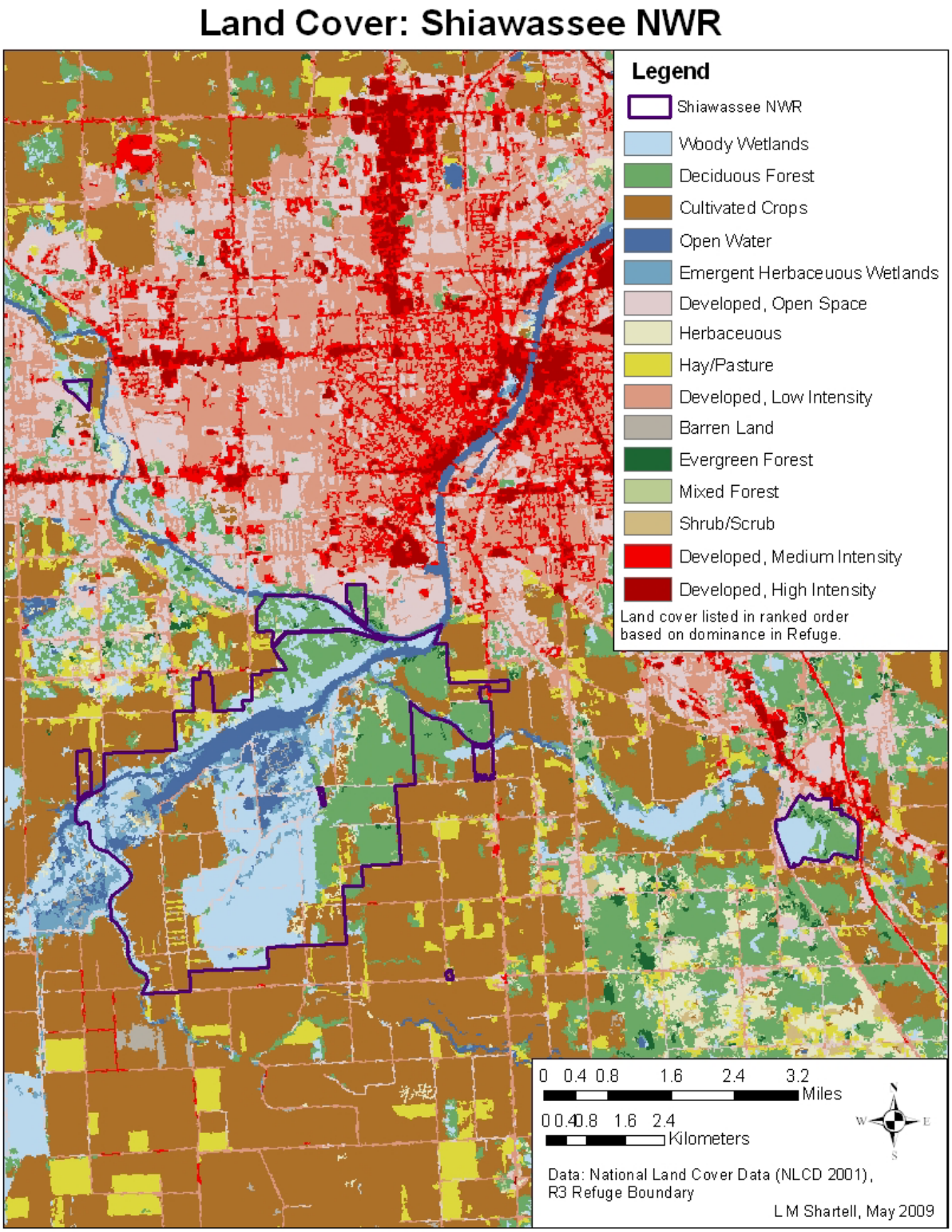


Map 11.

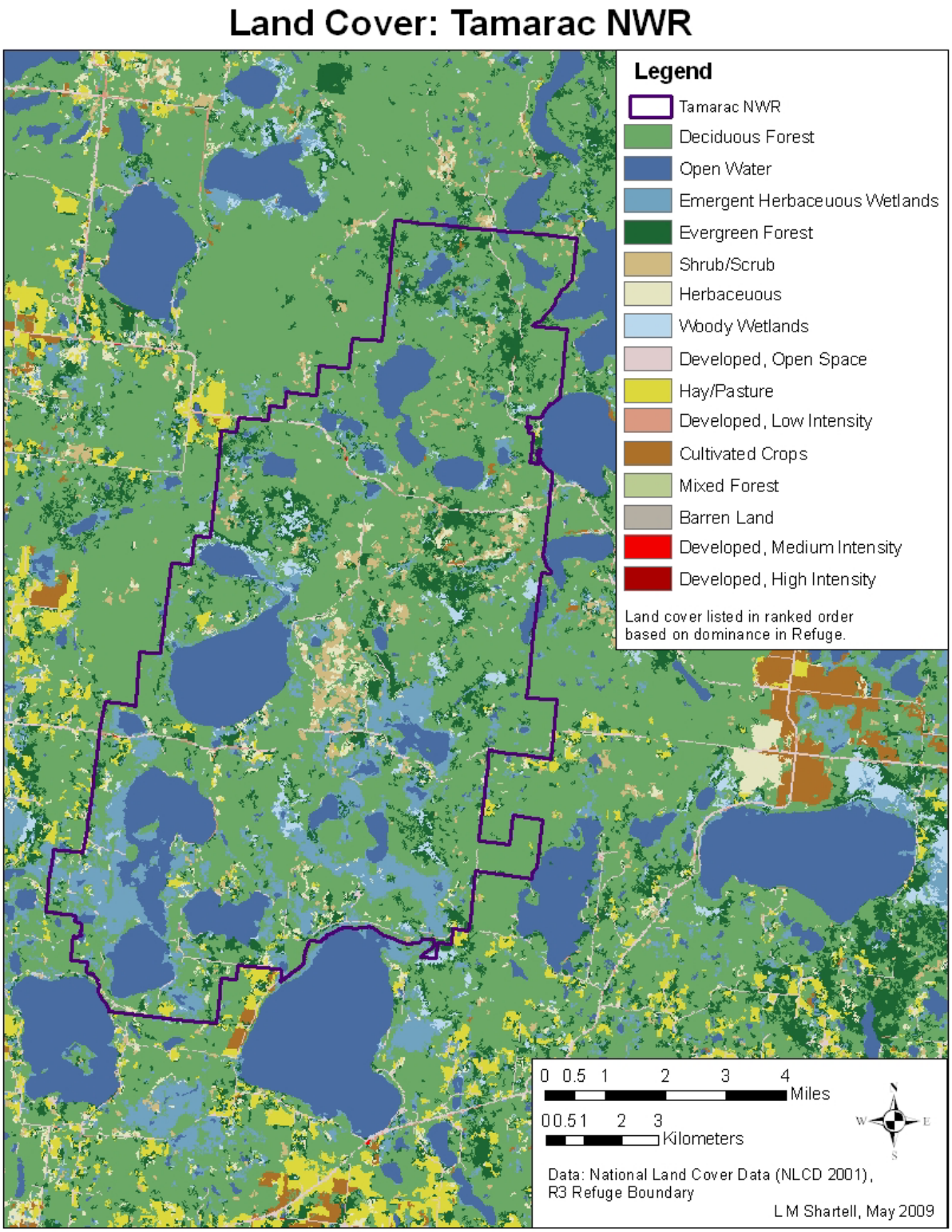
Land Cover: Sherburne NWR



Map 12.

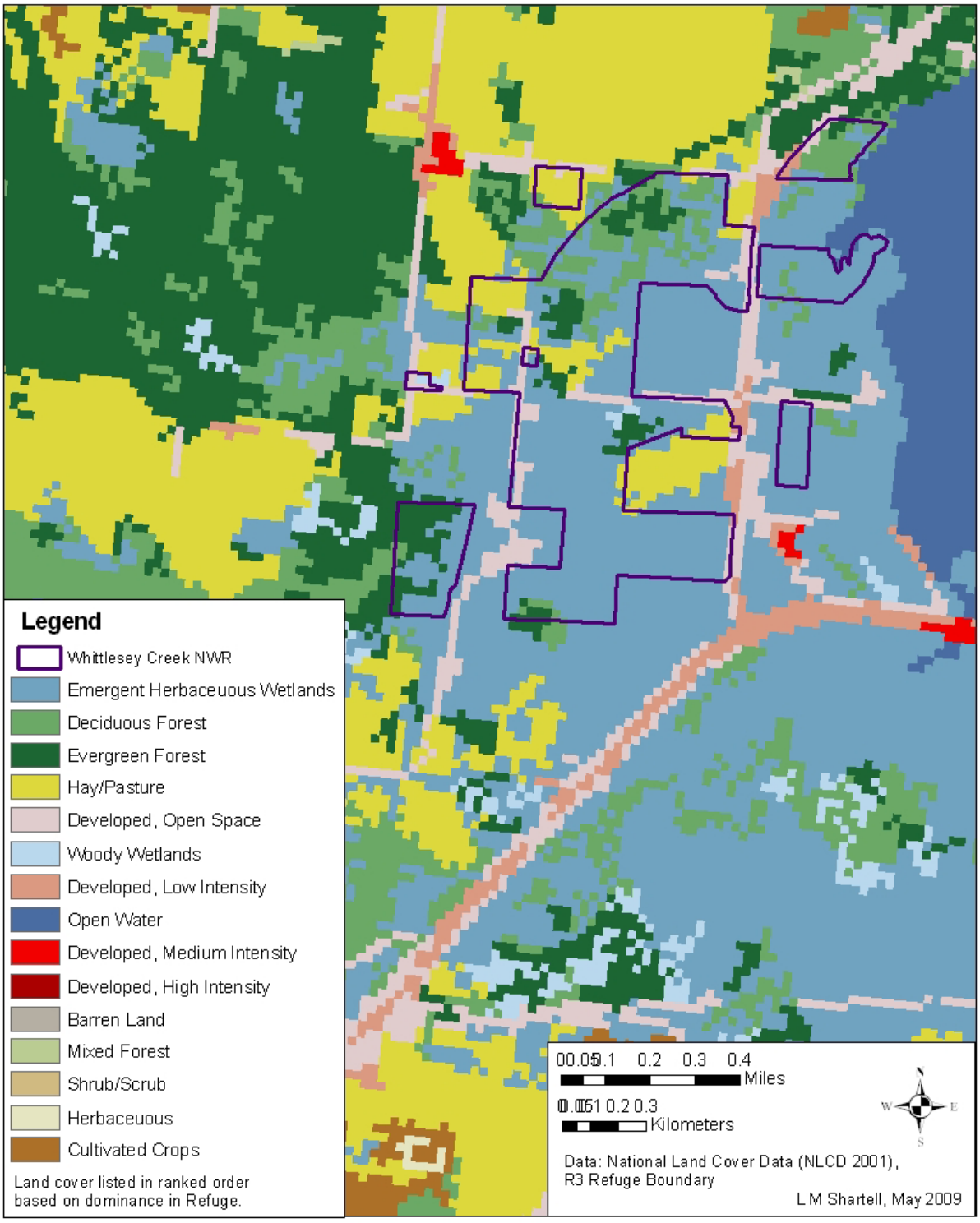

Land Cover: Shiawassee NWR
Legend
Shiawassee NWR
Woody Wetlands
Deciduous Forest
Cultivated Crops
Open Water
Emergent Herbaceuous Wetlands
Developed, Open Space
Herbaceuous
Hay/Pasture
Developed, Low Intensity
Barren Land
Evergreen Forest
Mixed Forest
Shrub/Scrub
Developed, Medium Intensity
Developed, High Intensity
Land cover listed in ranked order based on dominance in Refuge.
0 0.4 0.8 1.6 2.4 3.2
Miles
0 0.4 0.8 1.6 2.4
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), R3 Refuge Boundary
L M Shartell, May 2009

Map 13.


Land Cover: Tamarac NWR
Legend
Tamarac NWR
Deciduous Forest
Open Water
Emergent Herbaceuous Wetlands
Evergreen Forest
Shrub/Scrub
Herbaceuous
Woody Wetlands
Developed, Open Space
Hay/Pasture
Developed, Low Intensity
Cultivated Crops
Mixed Forest
Barren Land
Developed, Medium Intensity
Developed, High Intensity
Land cover listed in ranked order based on dominance in Refuge.
0 0.5 1 2 3 4
Miles
0 0.5 1 2 3
Kilometers
N
W
E
S
Data: National Land Cover Data (NLCD 2001), R3 Refuge Boundary
L M Shartell, May 2009

Map 14.

Land Cover: Whittlesey Creek NWR



Appendix 9. Soil series (STATSGO2, NRCS) and their characteristics by refuge, listed in ranked order by area. Refuges are listed alphabetically.

Table 1. Cedar Point NWR

Soil series	Texture	Drainage	Acres	Percent
Toledo	fine	Very poorly drained	1,912.61	73.48
Unknown			690.45	26.52
Total			**2,603.06**	**100.00**

Table 2. Crane Meadows NWR

Soil series	Texture	Drainage	Acres	Percent
Hubbard	sandy	Excessively drained	1,527.46	96.68
Pierz	coarse-loamy	Well drained	52.51	3.32
Total			**1,579.97**	**100.00**

Table 3. Detroit River IWR

Soil series	Texture	Drainage	Acres	Percent
Unknown			734.33	50.63
Lenawee	fine	Poorly drained	394.39	27.19
Nappanee	fine	Somewhat poorly drained	321.66	22.18
Total			**1,450.37**	**100.00**

Table 4. Green Bay NWR

Soil series	Texture	Drainage	Acres	Percent
Longrie	coarse-loamy	Well drained	271.56	84.02
Unknown			51.63	15.98
Total			**323.19**	**100.00**

Table 5. Horicon NWR

Soil series	Texture	Drainage	Acres	Percent
Houghton	not used	Very poorly drained	20,267.14	92.76
Lomira	fine-silty	Well drained	846.15	3.87
Varna	fine	Well drained	729.35	3.34
Hochheim	fine-loamy	Well drained	6.30	0.03
Total			**21,848.93**	**100.00**

Table 6. Kirtland's Warbler WMA

Soil series	Texture	Drainage	Acres	Percent
Grayling	not used	Excessively drained	3,643.22	55.19
Rubicon	sandy	Excessively drained	2,647.69	40.11
Graycalm	not used	Somewhat excessively drained	307.18	4.65
Histosols	not used	Very poorly drained	3.60	0.05
Total			**6,601.68**	**100.00**

Table 7. Necedah NWR

Soil series	Texture	Drainage	Acres	Percent
Newson	not used	Poorly drained	43,101.31	98.25
Plainfield	not used	Excessively drained	767.31	1.75
Total			**43,868.62**	**100.00**

Table 8. Ottawa NWR

Soil series	Texture	Drainage	Acres	Percent
Toledo	fine	Very poorly drained	5,721.00	96.43
Unknown			211.98	3.57
Total			**5,932.98**	**100.00**

Table 9. Rice Lake NWR

Soil series	Texture	Drainage	Acres	Percent
Greenwood	not used	Very poorly drained	8,580.01	42.40
Warba	fine-loamy	Moderately well drained	4,813.15	23.78
Water			3,593.26	17.76
Ahmeek	coarse-loamy	Well drained	1,572.86	7.77
Cromwell	sandy	Somewhat excessively drained	1,109.97	5.48
Winterfield	not used	Somewhat poorly drained	501.72	2.48
Pengilly	coarse-loamy	Poorly drained	66.23	0.33
Total			**20,237.21**	**100.00**

Table 10. Seney NWR

Soil series	Texture	Drainage	Acres	Percent
Dawson	sandy or sandy-skeletal	Very poorly drained	89,943.48	94.30
Sturgeon	coarse-silty over sandy	Somewhat poorly drained	4,029.94	4.23
Karlin	sandy	Somewhat excessively drained	960.89	1.01
Blue Lake	sandy	Well drained	442.19	0.46
Total			**95,376.50**	**100.00**

Table 11. Sherburne NWR

Soil series	Texture	Drainage	Acres	Percent
Zimmerman	not used	Excessively drained	30,398.94	98.58
Mora	coarse-loamy	Moderately well drained	436.81	1.42
Total			**30,835.75**	**100.00**

Table 12. Shiawassee NWR

Soil series	Texture	Drainage	Acres	Percent
Tappan	fine-loamy	Poorly drained	4,944.18	51.72
Shoals	fine-loamy	Somewhat poorly drained	4,324.09	45.24
Bach	coarse-silty	Poorly drained	290.47	3.04
Total			**9,558.74**	**100.00**

Table 13. Tamarac NWR

Soil series	Texture	Drainage	Acres	Percent
Snellman	fine-loamy	Well drained	21,802.24	49.19
Mahtomedi	not used	Excessively drained	19,464.88	43.92
Water			3,052.49	6.89
Total			**44,319.61**	**100.00**

Table 14. Whittlesey Creek NWR

Soil series	Texture	Drainage	Acres	Percent
Hibbing	fine	Well drained	292.19	100.00
Total			**292.19**	**100.00**

Appendix 10. Landscape metrics by ecoregion. Ecoregions are listed alphabetically. Codes used are: NP = number of patches, PD = patch density, LPI = largest patch index, LSI = landscape shape index, AREA_MN = mean patch area, PR= patch richness, SHDI = Shannon's diversity index, SIDI = Simpson's diversity index, SHEI = Shannon's evenness index, SIEI = Simpson's evenness index (for descriptions see Table 5).

Ecoregion	NP	PD	LPI	LSI	AREA_MN	PR	SHDI	SIDI	SHEI	SIEI
Alexandria Moraine-Hardwood Hills	246,820	17.44	0.99	427.49	5.73	15	1.87	0.81	0.69	0.86
Anoka Sand Plain	112,754	23.20	0.69	295.57	4.31	15	2.13	0.85	0.79	0.91
Central Wisconsin Sand Plain	114,850	17.55	2.10	322.92	5.70	15	2.21	0.86	0.82	0.92
Door Peninsula	31	25.35	69.54	4.65	3.95	8	0.95	0.45	0.45	0.51
Kirtland's Warbler High Sand Plains	141,061	18.52	1.07	340.88	5.40	15	2.07	0.84	0.76	0.90
Maumee Lake Plain	12,682	6.84	7.43	88.99	14.62	14	1.37	0.56	0.52	0.61
Mille Lacs Uplands	230,039	14.82	6.28	401.98	6.75	15	1.83	0.77	0.68	0.83
Pine Moraine and Outwash Plains	197,518	16.13	13.48	372.70	6.20	15	1.87	0.77	0.69	0.82
Saginaw Clay Lake and Till Plain	78,747	14.83	0.63	228.29	6.74	15	1.75	0.71	0.65	0.77
Seney Lake Plains	44,480	12.43	6.40	231.25	8.05	15	1.41	0.64	0.52	0.69
Southern Green Bay Lobe	142,017	12.61	3.48	316.64	7.93	15	1.71	0.71	0.63	0.76
St. Louis Moraines	108,889	16.31	13.13	286.99	6.13	15	1.65	0.69	0.61	0.73
Superior-Ashland Clay Plain	68,176	12.92	5.80	247.04	7.74	15	1.58	0.66	0.58	0.70
Toimi Uplands	111,377	18.17	4.08	316.70	5.51	15	1.82	0.78	0.67	0.83
Western Paleozoic Plateau	144,252	10.18	1.17	309.92	9.83	15	1.53	0.63	0.57	0.67

Appendix 11. Landscape metrics by land cover for each ecoregion. Ecoregions are listed alphabetically. Codes used are: NP = number of patches, PD = patch density, LPI = largest patch index, LSI = landscape shape index, AREA_MN = mean patch area.

Table 1. Alexandria Moraine-Hardwood Hills

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	7,110	0.50	0.40	87.81	18.07
Developed, Open Space	7,754	0.55	0.48	384.22	7.91
Developed, Low Intensity	4,287	0.30	0.02	134.01	1.95
Developed, Medium Intensity	1,016	0.07	0.00	59.14	1.40
Developed, High Intensity	380	0.03	0.00	28.40	1.85
Barren Land	179	0.01	0.00	20.08	1.95
Deciduous Forest	45,090	3.19	0.99	387.17	6.35
Evergreen Forest	18,200	1.29	0.01	233.83	1.17
Mixed Forest	1,520	0.11	0.00	64.79	0.70
Shrub/Scrub	10,228	0.72	0.00	169.89	1.42
Herbaceous	42,820	3.03	0.13	368.78	1.54
Pasture/Hay	44,499	3.14	0.08	391.94	6.70
Cultivated Crops	23,559	1.66	0.32	279.88	18.35
Woody Wetlands	7,809	0.55	0.01	153.22	1.18
Emergent Herbaceous Wetlands	32,369	2.29	0.10	336.03	2.65

Table 2. Anoka Sand Plain

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	1395	0.287	0.1084	52.831	13.3605
Developed, Open Space	10188	2.0961	0.189	233.5129	2.8038
Developed, Low Intensity	7352	1.5126	0.1681	196.1049	4.4815
Developed, Medium Intensity	5568	1.1456	0.0716	169.3055	2.9923
Developed, High Intensity	1987	0.4088	0.2526	70.2591	4.4793
Barren Land	60	0.0123	0.0027	12.6333	1.3425
Deciduous Forest	14473	2.9777	0.3178	230.7167	6.0464
Evergreen Forest	7543	1.5519	0.0813	133.7066	1.9128
Mixed Forest	751	0.1545	0.0006	44.6711	0.6914
Shrub/Scrub	2665	0.5483	0.0031	82.7978	1.0658
Herbaceous	13452	2.7676	0.011	205.2904	1.3088
Pasture/Hay	18839	3.876	0.1411	231.3687	3.757
Cultivated Crops	9045	1.8609	0.6855	163.9007	14.5413
Woody Wetlands	1653	0.3401	0.0084	69.2483	1.1392
Emergent Herbaceous Wetlands	17783	3.6587	0.4823	244.8843	2.9895

Table 3. Central Wisconsin Sand Plain

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	1715	0.2621	1.5384	49.4371	18.3994
Developed, Open Space	5149	0.7868	0.6132	264.9555	6.6582
Developed, Low Intensity	4024	0.6149	0.0883	137.4005	2.9679
Developed, Medium Intensity	1156	0.1766	0.0123	71.7054	2.1883
Developed, High Intensity	488	0.0746	0.0083	32.6471	2.2349
Barren Land	186	0.0284	0.0014	18.1939	1.1492
Deciduous Forest	18537	2.8326	1.2517	286.3952	8.9426
Evergreen Forest	12288	1.8777	0.1524	181.8973	4.1194
Mixed Forest	15895	2.4288	0.0206	244.1409	1.915
Shrub/Scrub	9030	1.3798	0.0178	184.2565	1.621
Herbaceous	19520	2.9828	0.0517	267.0333	2.2036
Pasture/Hay	2390	0.3652	0.0558	82.5693	8.2733
Cultivated Crops	5305	0.8106	2.0961	159.5155	26.2995
Woody Wetlands	10565	1.6144	0.5201	204.5299	5.842
Emergent Herbaceous Wetlands	8602	1.3144	0.8406	192.4845	5.5008

Table 4. Door Peninsula

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	6	4.9056	0.4415	2.375	0.195
Developed, Open Space	1	0.8176	2.2811	3.4167	2.79
Barren Land	13	10.6287	7.6527	6.6897	1.3915
Deciduous Forest	4	3.2704	69.5364	3.0952	22.14
Mixed Forest	1	0.8176	0.3679	1.8	0.45
Shrub/Scrub	3	2.4528	3.2377	4.65	2.94
Herbaceous	2	1.6352	1.1773	2.4	0.945
Emergent Herbaceous Wetlands	1	0.8176	0.4415	1.6	0.54

Table 5. Kirtland's Warbler High Sand Plains

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	1076	0.1413	1.0736	32.917	24.5261
Developed, Open Space	11084	1.4555	0.159	327.2642	4.1067
Developed, Low Intensity	4946	0.6495	0.0295	171.8232	3.1824
Developed, Medium Intensity	1070	0.1405	0.0112	65.0966	1.7659
Developed, High Intensity	234	0.0307	0.0107	25.4371	2.1865
Barren Land	455	0.0597	0.0061	34.6281	1.9493
Deciduous Forest	13290	1.7451	0.9406	223.3394	14.1903
Evergreen Forest	17227	2.2621	0.2289	227.1643	10.0098
Mixed Forest	29483	3.8714	0.0119	336.3366	1.5637
Shrub/Scrub	14237	1.8695	0.0351	213.0918	1.8019
Herbaceous	25347	3.3283	0.1473	299.3351	3.1563
Pasture/Hay	1057	0.1388	0.0196	47.5386	4.6091
Cultivated Crops	2673	0.351	0.0197	95.5848	3.4755
Woody Wetlands	9178	1.2052	0.9313	197.1852	13.6533
Emergent Herbaceous Wetlands	9704	1.2742	0.0372	198.9447	1.8914

Table 6. Maumee Lake Plain

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	555	0.2993	0.5116	31.2238	16.5303
Developed, Open Space	2197	1.1847	0.4456	140.484	6.7126
Developed, Low Intensity	2208	1.1907	0.4523	104.8507	4.2053
Developed, Medium Intensity	1360	0.7334	0.1901	77.7297	2.3927
Developed, High Intensity	559	0.3014	0.0826	37.8817	2.7564
Barren Land	184	0.0992	0.1153	18.583	7.4299
Deciduous Forest	2067	1.1146	0.4822	68.1551	4.9859
Evergreen Forest	47	0.0253	0.0036	10.0408	1.1087
Mixed Forest	6	0.0032	0.0007	3.6154	0.63
Herbaceous	1882	1.0149	0.0167	71.5231	1.2552
Pasture/Hay	78	0.0421	0.0349	21.125	18.8838
Cultivated Crops	214	0.1154	7.4297	62.3866	559.3033
Woody Wetlands	233	0.1256	0.0042	26.4513	1.2218
Emergent Herbaceous Wetlands	1092	0.5889	0.6798	49.342	10.9003

Table 7. Mille Lacs Uplands

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	2510	0.1617	3.3405	39.0519	33.3204
Developed, Open Space	9429	0.6076	0.5888	330.4375	4.7905
Developed, Low Intensity	4390	0.2829	0.0156	140.4199	1.9907
Developed, Medium Intensity	1031	0.0664	0.0035	59.0965	1.4585
Developed, High Intensity	313	0.0202	0.0011	25.6452	1.7206
Barren Land	62	0.004	0.003	11.3151	1.9002
Deciduous Forest	27690	1.7842	6.2835	336.9661	23.1164
Evergreen Forest	25367	1.6345	0.0358	282.0732	1.8261
Mixed Forest	2238	0.1442	0.0003	79.5204	0.7243
Shrub/Scrub	4075	0.2626	0.0036	101.9482	1.1826
Herbaceous	38816	2.5011	0.009	348.3037	1.477
Pasture/Hay	30248	1.949	0.0847	306.4344	8.7587
Cultivated Crops	14083	0.9074	0.1157	189.9919	11.7297
Woody Wetlands	20591	1.3268	0.2246	250.6425	3.5774
Emergent Herbaceous Wetlands	49196	3.1699	0.1525	434.0637	3.2172

Table 8. Pine Moraine and Outwash Plains

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	5362	0.4378	3.3287	65.1216	25.1706
Developed, Open Space	9000	0.7348	0.1702	278.3211	3.5732
Developed, Low Intensity	2486	0.203	0.0229	96.7287	1.7923
Developed, Medium Intensity	483	0.0394	0.0016	39.8916	1.2777
Developed, High Intensity	160	0.0131	0.0026	18.7815	1.9597
Barren Land	176	0.0144	0.0025	19.3894	1.6057
Deciduous Forest	24206	1.9762	13.4783	349.6233	22.1068
Evergreen Forest	36521	2.9816	0.1093	358.4123	3.1672
Mixed Forest	1804	0.1473	0.0056	73.3529	0.8089
Shrub/Scrub	22471	1.8346	0.0389	249.2295	1.932
Herbaceous	19484	1.5907	0.016	234.853	1.2171
Pasture/Hay	18423	1.5041	0.0762	222.0911	6.178
Cultivated Crops	10738	0.8767	0.211	155.5572	8.3063
Woody Wetlands	16426	1.341	0.0492	246.8433	2.6499
Emergent Herbaceous Wetlands	29778	2.4311	0.1822	336.0072	2.8936

Table 9. Saginaw Clay Lake and Till Plain

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	1021	0.1923	0.1036	54.6334	4.6644
Developed, Open Space	9462	1.7822	0.0424	200.4982	2.7916
Developed, Low Intensity	6861	1.2923	0.3929	227.2842	4.9398
Developed, Medium Intensity	3379	0.6365	0.1178	124.5798	2.7658
Developed, High Intensity	984	0.1853	0.0258	45.6667	2.761
Barren Land	1671	0.3147	0.011	65.4428	2.1673
Deciduous Forest	11180	2.1058	0.0961	220.7895	5.1246
Evergreen Forest	2952	0.556	0.0084	88.5277	1.5463
Mixed Forest	3454	0.6506	0.0026	102.9245	0.8937
Shrub/Scrub	1609	0.3031	0.0052	67.764	0.8683
Herbaceous	6942	1.3076	0.0135	150.024	1.8271
Pasture/Hay	11612	2.1872	0.0327	150.7372	4.0256
Cultivated Crops	7985	1.504	0.2312	139.2706	33.058
Woody Wetlands	7554	1.4229	0.6327	171.5348	7.4493
Emergent Herbaceous Wetlands	2081	0.392	0.0303	84.5058	1.989

Table 10. Seney Lake Plain

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	563	0.1573	0.0542	31.9429	7.021
Developed, Open Space	2041	0.5704	0.0485	127.8549	2.7869
Developed, Low Intensity	494	0.138	0.0085	50.5385	2.2212
Developed, Medium Intensity	89	0.0249	0.0014	15.322	0.8596
Developed, High Intensity	6	0.0017	0.0002	3.25	0.525
Barren Land	45	0.0126	0.0015	10.1556	0.982
Deciduous Forest	4057	1.1337	0.3725	99.5222	7.3412
Evergreen Forest	10659	2.9787	0.262	204.5196	3.8501
Mixed Forest	5767	1.6116	0.0297	140.8189	1.5723
Shrub/Scrub	739	0.2065	0.0675	44.1148	1.326
Herbaceous	2468	0.6897	0.0825	85.7258	3.2533
Pasture/Hay	1	0.0003	0.0003	1	0.9
Cultivated Crops	29	0.0081	0.0027	7.3095	1.3221
Woody Wetlands	5395	1.5076	6.4009	240.5818	36.7831
Emergent Herbaceous Wetlands	12127	3.3889	2.4761	291.4662	4.9147

Table 11. Southern Green Bay Lobe

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	2651	0.2353	0.3966	53.0245	13.5947
Developed, Open Space	18618	1.6528	0.0174	313.3314	2.1866
Developed, Low Intensity	12767	1.1334	0.2666	268.0224	3.5954
Developed, Medium Intensity	3960	0.3516	0.0356	135.8605	2.6287
Developed, High Intensity	1425	0.1265	0.0137	57.4387	2.1223
Barren Land	668	0.0593	0.0037	33.4487	1.8341
Deciduous Forest	28946	2.5697	0.1891	271.7448	3.4932
Evergreen Forest	1887	0.1675	0.0058	61.5071	2.1214
Mixed Forest	1234	0.1096	0.0005	57.8868	0.8124
Shrub/Scrub	10055	0.8926	0.004	168.0643	1.0442
Herbaceous	8859	0.7865	0.0022	154.4951	0.9633
Pasture/Hay	16923	1.5024	0.0653	248.8483	11.5417
Cultivated Crops	8481	0.7529	3.4776	260.1128	64.8988
Woody Wetlands	10799	0.9587	0.1371	167.3002	4.3724
Emergent Herbaceous Wetlands	14744	1.3089	0.6721	215.8165	4.8164

Table 12. St. Louis Moraines

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	2735	0.4098	0.3981	60.8909	20.4485
Developed, Open Space	5086	0.762	0.0389	187.29	2.7801
Developed, Low Intensity	1208	0.181	0.0103	69.2651	1.6458
Developed, Medium Intensity	434	0.065	0.0033	39.5284	1.603
Developed, High Intensity	104	0.0156	0.0115	14.8785	2.4395
Barren Land	118	0.0177	0.0632	14.0178	5.4267
Deciduous Forest	10429	1.5625	13.1346	266.1444	33.9394
Evergreen Forest	24024	3.5992	0.1618	311.4707	2.8352
Mixed Forest	1525	0.2285	0.0023	68.8291	0.802
Shrub/Scrub	10920	1.636	0.0154	187.2093	1.8428
Herbaceous	12679	1.8995	0.0141	190.1184	1.4205
Pasture/Hay	6515	0.9761	0.0608	124.6866	4.3502
Cultivated Crops	1109	0.1661	0.0072	51.9691	2.5626
Woody Wetlands	16607	2.488	0.3286	225.8312	3.6203
Emergent Herbaceous Wetlands	15396	2.3066	0.1526	237.2293	2.6695

Table 13. Superior-Ashland Clay Plain

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	1592	0.3017	0.1373	57.6274	3.1835
Developed, Open Space	4997	0.947	0.0442	170.7558	2.7219
Developed, Low Intensity	1856	0.3518	0.1192	99.9744	3.1283
Developed, Medium Intensity	511	0.0968	0.0334	43.6535	2.287
Developed, High Intensity	159	0.0301	0.0035	20.6273	1.7015
Barren Land	223	0.0423	0.321	14.4938	10.442
Deciduous Forest	10305	1.953	5.7952	229.6593	28.1819
Evergreen Forest	15616	2.9596	0.405	269.6525	5.3553
Mixed Forest	10060	1.9066	0.3118	233.1556	3.0566
Shrub/Scrub	1354	0.2566	0.0224	62.7825	1.5737
Herbaceous	4195	0.795	0.0081	116.1554	1.6013
Pasture/Hay	4425	0.8386	0.1927	115.1423	10.2462
Cultivated Crops	1830	0.3468	0.0261	73.6147	4.1797
Woody Wetlands	3881	0.7355	0.1223	109.8834	3.218
Emergent Herbaceous Wetlands	7172	1.3593	0.4802	157.8158	2.8277

Table 14. Toimi Uplands

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	1298	0.2117	0.0802	55.1241	8.7133
Developed, Open Space	3281	0.5351	0.0434	165.9904	3.6443
Developed, Low Intensity	1147	0.1871	0.0128	66.8138	1.6487
Developed, Medium Intensity	320	0.0522	0.014	34.0974	1.6543
Developed, High Intensity	118	0.0192	0.0053	16.165	1.9968
Barren Land	185	0.0302	0.098	19.0249	7.0258
Deciduous Forest	14738	2.4037	4.0828	311.6991	15.2794
Evergreen Forest	21435	3.496	0.3212	301.396	2.3279
Mixed Forest	2155	0.3515	0.0012	79.8179	1.0902
Shrub/Scrub	8596	1.402	0.0059	161.853	1.2334
Herbaceous	16374	2.6706	0.0458	224.8073	1.6472
Pasture/Hay	5683	0.9269	0.3	116.971	5.7481
Cultivated Crops	1557	0.2539	0.1634	56.3513	4.7742
Woody Wetlands	16435	2.6805	3.458	224.9753	8.892
Emergent Herbaceous Wetlands	18055	2.9447	0.6163	272.7675	4.6888

Table 15. Western Paleozoic Plateau

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	2432	0.1715	0.0542	65.6091	4.9055
Developed, Open Space	21520	1.5179	0.6365	384.2014	5.2613
Developed, Low Intensity	27004	1.9048	0.1925	388.5136	4.3302
Developed, Medium Intensity	13558	0.9563	0.9482	295.9775	6.949
Developed, High Intensity	7127	0.5027	0.7423	142.4005	5.2588
Barren Land	1365	0.0963	0.0121	54.4413	2.0029
Deciduous Forest	19133	1.3496	0.0838	250.1776	4.8798
Evergreen Forest	739	0.0521	0.005	38.584	1.9028
Mixed Forest	1334	0.0941	0.0007	63.25	0.8158
Shrub/Scrub	1572	0.1109	0.0029	67.0175	0.7451
Herbaceous	14931	1.0532	0.0022	210.6167	1.1506
Pasture/Hay	12028	0.8484	0.0755	171.356	4.5637
Cultivated Crops	8842	0.6237	1.1724	171.9775	94.4619
Woody Wetlands	8417	0.5937	0.0329	159.3339	3.5112
Emergent Herbaceous Wetlands	4250	0.2998	0.0599	104.1526	1.7194

Appendix 12. Landscape metrics by refuge. Refuges are listed alphabetically. Codes used are: NP = number of patches, PD = patch density, LPI = largest patch index, LSI = landscape shape index, AREA_MN = mean patch area, PR = patch richness, SHDI = Shannon's diversity index, SIDI = Simpson's diversity index, SHEI = Shannon's evenness index, SIEI = Simpson's evenness index (for descriptions see Table 5).

Refuge	NP	PD	LPI	LSI	AREA_MN	PR	SHDI	SIDI	SHEI	SIEI
Cedar Point National Wildlife Refuge	26	2.47	65.89	4.60	40.46	5	0.71	0.46	0.44	0.57
Crane Meadows National Wildlife Refuge	248	38.99	7.54	14.01	2.57	11	1.60	0.75	0.67	0.82
Detroit River International Wildlife Refuge	160	27.33	17.99	10.52	3.66	13	1.64	0.69	0.64	0.75
Green Bay National Wildlife Refuge	30	22.89	65.25	4.94	4.37	8	0.99	0.49	0.48	0.56
Horicon National Wildlife Refuge	642	7.26	42.12	19.49	13.78	11	1.14	0.57	0.47	0.63
Kirtland's Warbler Wildlife Management Area	816	30.56	4.19	23.03	3.27	13	1.67	0.75	0.65	0.82
Necedah National Wildlife Refuge	3,519	19.84	10.69	61.68	5.04	11	1.89	0.80	0.79	0.88
Ottawa National Wildlife Refuge	244	10.18	39.12	12.41	9.82	9	1.11	0.58	0.51	0.65
Rice Lake National Wildlife Refuge	915	11.23	21.58	22.40	8.90	12	1.50	0.71	0.60	0.78
Seney National Wildlife Refuge	4,874	12.62	21.85	100.69	7.92	14	1.34	0.66	0.51	0.71
Sherburne National Wildlife Refuge	2,536	20.45	13.64	45.91	4.89	12	1.77	0.79	0.71	0.86
Shiawassee National Wildlife Refuge	776	20.08	9.99	23.14	4.98	15	1.84	0.80	0.68	0.85
Tamarac National Wildlife Refuge	2,392	13.47	47.85	40.79	7.42	14	1.44	0.65	0.55	0.70
Whittlesey Creek National Wildlife Refuge	64	54.37	28.52	7.34	1.84	8	1.22	0.58	0.59	0.66

Appendix 13. Landscape metrics for land cover for each refuge. Refuges are listed alphabetically. Codes used are: NP = number of patches, PD = patch density, LPI = largest patch index, LSI = landscape shape index, AREA_MN = mean patch area.

Table 1. Cedar Point National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	14	1.33	26.70	5.79	24.68
Developed, Open Space	4	0.38	0.22	5.06	1.42
Developed, Low Intensity	6	0.57	0.17	4.15	0.59
Barren Land	1	0.10	0.39	1.71	4.05
Emergent Herbaceous Wetlands	1	0.10	65.89	4.35	693.09

Table 2. Crane Meadows National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	10	1.57	0.75	3.06	0.68
Developed, Open Space	24	3.77	0.13	6.15	0.36
Developed, Low Intensity	1	0.16	0.07	1.20	0.45
Deciduous Forest	55	8.65	3.61	13.19	2.20
Evergreen Forest	7	1.10	0.11	3.92	0.42
Shrub/Scrub	3	0.47	0.10	1.88	0.45
Herbaceous	40	6.29	0.99	10.79	0.97
Hay/Pasture	37	5.82	3.47	9.23	1.93
Cultivated Crops	18	2.83	7.54	6.03	7.44
Woody Wetlands	6	0.94	0.17	3.20	0.38
Emergent Herbaceous Wetlands	47	7.39	7.54	11.71	5.30

Table 3. Detroit River International Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	18	3.07	17.99	5.93	16.98
Developed, Open Space	11	1.88	0.32	5.00	0.62
Developed, Low Intensity	26	4.44	0.43	7.77	0.80
Developed, Medium Intensity	5	0.85	0.23	3.36	0.52
Developed, High Intensity	2	0.34	0.05	1.75	0.18
Barren Land	20	3.42	0.97	7.27	0.99
Decidous Forest	11	1.88	6.96	6.71	6.27
Shrub/Scrub	1	0.17	0.08	1.80	0.45
Herbaceous	10	1.71	2.20	5.26	2.10
Hay/Pasture	1	0.17	0.38	1.60	2.25
Cultivated Crops	8	1.37	5.04	3.80	8.34
Woody Wetlands	18	3.07	1.15	7.15	1.97
Emergent Herbaceous Wetlands	29	4.95	1.58	9.58	1.20

Table 4. Green Bay National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	4	3.05	0.41	2.00	0.25
Developed, Open Space	1	0.76	2.13	3.42	2.79
Barren Land	14	10.68	11.06	6.97	1.90
Deciduous Forest	4	3.05	65.25	3.10	22.25
Mixed Forest	1	0.76	0.34	1.80	0.45
Shrub/Scrub	3	2.29	3.02	4.65	2.94
Herbaceous	2	1.53	1.10	2.40	0.95
Emergent Herbaceous Wetlands	1	0.76	0.41	1.60	0.54

Table 5. Horicon National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	111	1.25	14.50	16.69	19.34
Developed, Open Space	35	0.40	0.23	18.74	2.75
Developed, Low Intensity	24	0.27	0.09	7.38	0.92
Developed, Medium Intensity	3	0.03	0.05	3.95	2.55
Deciduous Forest	93	1.05	0.07	14.71	1.14
Shrub/Scrub	17	0.19	0.03	5.84	0.82
Herbaceous	7	0.08	0.01	3.77	0.54
Hay/Pasture	13	0.15	0.10	4.65	1.12
Cultivated Crops	71	0.80	1.07	18.38	12.45
Woody Wetlands	170	1.92	0.50	21.03	1.63
Emergent Herbaceous Wetlands	98	1.11	42.12	19.14	53.83

Table 6. Kirtland's Warbler Wildlife Management Area

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	3	0.11	0.27	2.43	3.27
Developed, Open Space	175	6.55	0.34	23.17	0.98
Developed, Low Intensity	48	1.80	0.07	8.87	0.43
Developed, Medium Intensity	1	0.04	0.01	1.00	0.27
Barren Land	1	0.04	0.02	1.40	0.45
Deciduous Forest	35	1.31	0.43	8.82	1.51
Evergeen Forest	146	5.47	4.19	15.54	7.04
Mixed Forest	98	3.67	0.26	16.30	0.99
Shrub/Scrub	117	4.38	1.87	14.72	3.58
Herbaceous	129	4.83	2.49	14.25	5.20
Cultivated Crops	2	0.07	0.00	1.33	0.09
Woody Wetlands	42	1.57	2.71	9.70	3.95
Emergent Herbaceous Wetlands	19	0.71	0.49	8.10	1.89

Table 7. Necedah National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	95	0.54	1.66	14.32	9.70
Developed, Open Space	83	0.47	1.81	41.04	6.88
Developed, Low Intensity	8	0.05	0.01	3.50	0.28
Deciduous Forest	490	2.76	10.69	53.66	12.57
Evergreen Forest	164	0.92	0.26	20.09	2.34
Mixed Forest	316	1.78	0.21	32.53	1.30
Shrub/Scrub	557	3.14	0.39	46.45	1.94
Herbaceous	757	4.27	0.47	54.94	2.21
Cultivated Crops	56	0.32	0.67	16.19	6.93
Woody Wetlands	508	2.86	5.33	47.66	6.27
Emergent Herbaceous Wetlands	485	2.73	3.16	49.02	6.12

Table 8. Ottawa National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	53	2.21	12.90	9.39	9.54
Developed, Open Space	50	2.09	0.35	14.22	1.16
Developed, Low Intensity	53	2.21	0.33	11.30	0.88
Developed, Medium Intensity	6	0.25	0.09	3.36	0.66
Barren Land	2	0.08	0.03	2.25	0.63
Deciduous Forest	2	0.08	0.05	2.22	0.90
Herbaceous	4	0.17	0.05	2.83	0.74
Cultivated Crops	34	1.42	2.95	8.23	10.37
Emergent Herbaceous Wetlands	40	1.67	39.12	12.48	35.57

Table 9. Rice Lake National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	18	0.22	17.89	2.87	84.69
Developed, Open Space	66	0.81	0.26	19.60	1.65
Developed, Low Intensity	1	0.01	0.00	1.00	0.18
Deciduous Forest	146	1.79	21.58	20.86	24.15
Evergreen Forest	82	1.01	0.18	15.53	1.10
Mixed Forest	3	0.04	0.01	2.63	0.48
Shrub/Scrub	9	0.11	0.02	4.67	0.80
Herbaceous	193	2.37	0.32	23.50	1.27
Hay/Pasture	51	0.63	0.83	9.59	3.66
Cultivated Crops	8	0.10	0.08	4.56	2.05
Woody Wetlands	167	2.05	0.55	22.59	2.64
Emergent Herbaceous Wetlands	171	2.10	16.18	26.06	11.70

Table 10. Seney National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	151	0.39	0.47	18.57	11.73
Developed, Open Space	140	0.36	0.21	36.34	3.24
Developed, Low Intensity	97	0.25	0.01	15.74	0.58
Developed, Medium Intensity	14	0.04	0.00	4.71	0.46
Developed, High Intensity	1	0.00	0.00	1.00	0.45
Barren Land	1	0.00	0.00	1.60	0.45
Decidous Forest	222	0.57	0.39	25.03	4.66
Evergreen Forest	1,024	2.65	0.65	65.53	2.85
Mixed Forest	273	0.71	0.02	29.58	0.93
Shrub/Scrub	40	0.10	0.01	10.40	0.67
Herbaceous	264	0.68	0.16	29.93	2.57
Cultivated Crops	5	0.01	0.07	2.81	8.26
Woody Wetlands	1,196	3.10	21.85	130.05	14.52
Emergent Herbaceous Wetlands	1,446	3.74	10.84	124.91	9.69

Table 11. Sherburne National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	75	0.60	1.55	13.88	10.11
Developed, Open Space	87	0.70	0.46	24.91	2.30
Developed, Low Intensity	6	0.05	0.01	2.89	0.30
Deciduous Forest	382	3.08	6.61	40.80	8.25
Evergreen Forest	91	0.73	0.45	13.33	2.58
Mixed Forest	6	0.05	0.01	3.71	0.72
Shrub/Scrub	155	1.25	0.04	19.51	1.08
Herbaceous	570	4.60	0.24	42.81	1.46
Hay/Pasture	361	2.91	0.49	31.96	2.07
Cultivated Crops	238	1.92	10.64	28.97	11.59
Woody Wetlands	6	0.05	0.03	4.11	1.17
Emergent Herbaceous Wetlands	559	4.51	13.64	48.16	6.32

Table 12. Shiawassee National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	65	1.68	5.60	13.78	5.70
Developed, Open Space	75	1.94	0.78	19.16	1.93
Developed, Low Intensity	45	1.16	0.20	11.55	0.93
Developed, Medium Intensity	1	0.03	0.02	1.14	0.90
Developed, High Intensity	1	0.03	0.01	1.40	0.54
Barren Land	30	0.78	0.12	10.33	0.78
Deciduous Forest	68	1.76	9.81	14.28	12.43
Evergreen Forest	26	0.67	0.06	9.00	0.81
Mixed Forest	33	0.85	0.03	9.39	0.52
Shrub/Scrub	9	0.23	0.10	4.55	1.00
Herbaceous	64	1.66	0.25	14.53	1.24
Hay/Pasture	52	1.35	0.22	11.20	1.46
Cultivated Crops	89	2.30	4.33	13.78	9.43
Woody Wetlands	96	2.48	9.99	18.38	12.28
Emergent Herbaceous Wetlands	122	3.16	0.47	20.66	1.77

Table 13. Tamarac National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	106	0.60	3.95	9.83	26.40
Developed, Open Space	170	0.96	0.06	26.78	1.35
Developed, Low Intensity	21	0.12	0.02	8.42	1.11
Developed, Medium Intensity	2	0.01	0.00	1.86	0.50
Barren Land	2	0.01	0.00	2.57	0.54
Deciduous Forest	236	1.33	47.85	41.93	41.44
Evergreen Forest	652	3.67	0.64	49.99	2.40
Mixed Forest	11	0.06	0.01	5.41	0.57
Shrub/Scrub	234	1.32	0.29	24.32	2.10
Herbaceous	248	1.40	0.16	28.38	1.44
Hay/Pasture	70	0.39	0.07	13.83	1.55
Cultivated Crops	12	0.07	0.02	5.87	1.61
Woody Wetlands	191	1.08	0.14	25.34	1.82
Emergent Herbaceous Wetlands	437	2.46	1.75	40.44	4.65

Table 14. Whittlesey Creek National Wildlife Refuge

Land cover	NP	PD	LPI	LSI	AREA_MN
Open Water	1	0.85	0.08	1.00	0.09
Developed, Open Space	14	11.89	1.83	4.94	0.48
Developed, Low Intensity	2	1.70	0.31	1.40	0.23
Deciduous Forest	11	9.34	5.35	6.04	1.28
Evergreen Forest	10	8.49	3.06	4.88	1.23
Hay/Pasture	10	8.49	2.29	4.09	1.05
Woody Wetlands	2	1.70	0.38	1.67	0.32
Emergent Herbaceous Wetlands	14	11.89	28.52	6.54	5.20