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Winter Home-range Characteristics of American Marten (Martes americana) in Northern Wisconsin

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Abstract.—We estimated home-range size for American marten (*Martes americana*) in northern Wisconsin during the winter months of 2001–2004, and compared the proportion of cover-type selection categories (highly used, neutral and avoided) among home-ranges (95% fixed-kernel), core areas (50% fixed-kernel) and the study area. Average winter home-range size was 3.29 km^2 with home-ranges of males (n = 8, mean = 4.25 km^2) significantly larger than females (n = 5, mean = 2.32 km^2). Composition of cover-type selection categories in home-ranges differed significantly from what was available in the study area ($X^2 = 6.9145$, df = 2, $P > 0.0315$) with more highly used habitat and less avoided habitat than expected. Consistent with research in other regions, 72% of an American marten home-range contained highly used cover-types and 18% of a home-range contained avoided types with the remainder of the average home-range composed of neutral cover-types. This suggests that Wisconsin American martens select habitat at the home-range scale based on the occurrence of highly used and avoided cover types. Proportions of selection categories in core areas did not differ significantly from what was available in the study area or in home-ranges. Core areas were significantly smaller than home-ranges and this observation combined with the lack of cover-type selection at the core area scale suggests that American martens select core areas based upon micro-site features (*e.g.*, rest sites) rather than broad-scale cover types. The findings presented here may assist wildlife managers in management activities by identifying potentially suitable habitat.

Introduction

Literature on the ecology of American marten (*Martes americana*) in Wisconsin is scarce. This is unfortunate, as this species is important both culturally and ecologically within this region. For example, the American marten is a clan animal (Waabizheshi) of the Ojibwe people, thus is significant in many aspects of their culture. American martens are also the only state-listed endangered mammal (WI Statute 5529.415). Regionally, researchers and managers recognize the American marten as a forest-sensitive species and a mature forest indicator. The Eastern Region of the U.S. Forest Service lists the American marten as a Regional Forester Sensitive Species requiring National Forests to provide habitat for this species. In Michigan, the Ottawa National Forest planning process recently identified the American marten as one of four indicator species they will use to determine the success of implementation of the forest management plan (USDA, 2006). Despite its role, there is still a poor understanding of its landscape-scale habitat needs in Wisconsin and the Great Lakes region.

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American marten populations decreased across most of their range in Wisconsin due to habitat loss and exploitation in the early 1900s. The species was considered extirpated from Wisconsin in 1925 (Jackson, 1961) and was listed as state-endangered in 1972 (WI Statute 5529.415). Subsequently, American martens were reintroduced on the west (Chequamegon) and east (Nicolet) portions of the Chequamegon-Nicolet National Forest in Wisconsin; one reintroduction was near Eagle River (Nicolet) in 1975–1983 and the other near Clam Lake (Chequamegon) in 1987–1990 (Williams *et al.*, 2007). After reintroduction there was significant range expansion around the original release sites (Woodford In Litt.), subsequently populations decreased and there has been little evidence of range expansion since (Wydeven *et al.*, 2002; Gilbert *et al.*, 2005).

American marten home-range areas are reported as larger than expected based on body mass, with home-range areas of males larger than those of females (Buskirk and McDonald, 1989). Reported home-range areas of American martens vary due to several reasons including; the methods of determining home-ranges, the number of animals sampled and/or differences in habitat quality (Powell, 1994). Wright (1999) reported the average winter home-range (95% adaptive kernel estimator) of 21 American martens marked in the Nicolet population in Wisconsin was 3.7 km^2 (females, n = 6, mean = 2.7 km^2; males, n = 15, mean = 4.7 km^2). Home-range size often reflects habitat quality (Buskirk and McDonald, 1989; Potvin and Breton, 1997) as it relates to prey abundance (Thompson and Colgan, 1987; Gosse *et al.*, 2005), availability of suitable rest and den sites (Buskirk, 1984; Buskirk *et al.*, 1989; Spencer, 1987; Ruggiero *et al.*, 1998) and opportunities to escape from predators. Home-range estimates reported by Wright (1999) were characterized as small compared to estimates from other areas; he attributed this small size to favorable habitat conditions.

Across their geographic range, habitat types selected by American martens vary widely (Buskirk and Powell, 1994; Bissonette *et al.*, 1997; Potvin *et al.*, 2000). Typically, American martens are associated with late-successional coniferous forests in western Canada and western United States (Buskirk and Powell, 1994). American martens in the Great Lakes region reside in areas that are dominated by deciduous forest types. However, in the eastern portion of their range American martens use mixed coniferous and deciduous and deciduous-dominated stands (Chapin *et al.*, 1997; Potvin *et al.*, 2000). Wright (1999) used extensive radio-telemetry data and use-availability analysis to classify USDA Forest Service inventory cover-types, derived from Combined Data Systems (CDS) stand data (attributes collected from timber surveys including forest type and tree size density) as belonging to one of three habitat preference (here after referred to as selection) categories (preferred here after referred to as highly used, neutral or avoided). This categorization of cover-types relates the species composition, tree size and tree density characteristics of forest stands to many American marten life history requirements (Chapin *et al.*, 1997; Potvin *et al.*, 2000). Wright's classification scheme of cover-types was based upon second-order selection (Johnson, 1980) or comparisons of cover-type conditions at individual point locations to conditions available within animal's home-ranges.

The amount and configuration of these highly used cover-types within local areas may influence the suitability of those areas for American marten establishment of home-ranges (Fuller and Harrison, 2005). American martens are known to be negatively impacted by forest fragmentation demonstrated by low populations in clear-cut and open areas (Soutiere, 1979) and low percentages of open areas in home-ranges (Chapin *et al.*, 1998; Hargis *et al.*, 1999). Bissonette *et al.* (1997) reported that American martens will not establish home-ranges in areas that contain less than approximately 70% of suitable cover types. If the size and distribution of the resulting suitable areas is limiting then viable populations of American marten may not be capable of existing in the region.

Our objectives were to: (1) estimate winter home-range areas (95% fixed-kernel, area where an American marten ranges throughout the winter) and core areas (50% fixed-kernel, a smaller area representing the American marten's main winter activity center) and compare our home-range estimates to previous studies in Wisconsin and elsewhere; and (2) extrapolate Wright's second-order habitat selection categories to third-order (Johnson, 1980) by determining the proportions of cover-type selection categories (highly used, neutral, and avoided) within winter home-ranges and core areas: and comparing these proportions to those found in the study area

METHODS

The study was conducted on the Great Divide District of the Chequamegon-Nicolet National Forest, Ashland County, Wisconsin, U.S.A. (46°17′N, 90°45′W). The soils are comprised primarily of sandy-loam glacial tills, silt-covered glacial tills and sandy outwash. The climate of northern Wisconsin is characterized by long winters and relatively cool summers with Jan. average temperatures of −10.8 C and Jul. average temperatures of 18.7 C. Average precipitation is 76.2 cm and average annual snowfall is 127–152 cm.

The vegetative composition of the study area is typical of northern Wisconsin with a mosaic of forest cover types, size classes and forest structure. The most common cover type is the upland hardwood forest dominated by sugar maple (*Acer saccharum*), American basswood (*Tilia americana*), yellow birch (*Betula alleghaniensis*), red maple (*A. rubrum*), white ash (*Fraxinus americana*), red oak (*Quercus rubra*) and pockets of hemlock (*Tsuga canadensis*). The study area also has a lowland hardwood cover type dominated by black ash (*F. nigra*), American elm (*Ulmus americana*) and red maple. The coniferous cover-types are a lowland conifer cover-type consisting of black spruce (*Picea mariana*), northern white cedar (*Thuja occidentalis*) and tamarack (*Larix laricina*), and an upland conifer cover type consisting of red pine (*Pinus resinosa*), hemlock, balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*). The Aspen/Birch/Fir cover-type is comprised of quaking aspen (*Populus tremuloides*), paper birch (*B. papyrifera*) and bigtooth aspen (*P. grandidentata*). In addition to forested cover, open water and non-forested upland and lowland areas (less than 10% stocking of trees) are found within the study area.

American martens were live-trapped with Tomahawk traps models TLT106 and TLT108 (National Live Trap Co., Tomahawk, WI, U.S.A.) during the months of Sept.–Nov. and again from Jan.–Feb., 2001–2004. Traps were baited with beaver (*Castor canadensis*) meat supplemented with commercial lure (Hawbakers, Fort Louden, PA, U.S.A.). Captured animals were immobilized with ketamine hydrochloride and xylazine (0.1 mg/kg body mass). Animals were weighed, measured, sexed and a first premolar was removed for aging purposes (Matson's Laboratory, Milltown, MT, U.S.A.). American martens were fitted with radio collars equipped with mortality sensors (Telonics, Inc., Mesa, AZ, U.S.A.) and released when they became ambulatory. All animals were handled using protocols consistent with the recommendations of the American Society of Mammalogists (1998) and the project veterinarian.

American marten locations were estimated using azimuths derived from a vehicle-mounted 5-element yagi directional antenna, with either a TR-5 receiver (Telonics, Inc., Mesa, AZ, U.S.A.) or a Challenger Model 2000 receiver (Advanced Telemetry System, Isanti, Minnesota, U.S.A.). Azimuth readings were recorded from geo-referenced stations (corrected against a local base station) located throughout the study area and point locations were solved using the maximum likelihood estimator (Lenth, 1981) within the Locate II software (Nams, 1990).

Receiving stations were designated based on topography, known American marten home-range history and accessibility. All American marten locations were estimated from at least 3 azimuth readings recorded within 30 min of each other (Schmutz and White, 1990). Additional readings were collected until the calculated error ellipse was <0.2 km^2 and all additional readings were still within the 30-min time constraint.

We tested the precision of azimuth readings by placing radio collars at geo-referenced positions in the study area within known American marten home-ranges at approximately 1 m above ground surface. Observers measured the azimuth to each collar without knowledge of actual collar location. The true azimuth from the stations used in the test was calculated after White and Garrot (1990).

Radio telemetry locations collected during the months of Nov. to Apr. in the years 2001 to 2004 were used for analysis. Only individual American martens with $\geq$15 locations with a maximum error ellipse $\leq$0.2 km^2 were included. The home-range locations of American martens estimated in multiple years were compared using Multiple Response Permutation Procedures (MRPP; BLOSSOM software; Slauson *et al.*, 1991) to assess spatial independence. Successive locations or estimated areas of use from the same individual are never totally independent from each other (Proulx and O'Doherty, 2006) however, the MRPP test assess whether or not sets of spatial coordinates are statistically likely to have been drawn from a common pool (Slauson *et al.*, 1991). If home-ranges from the same individual in different years were spatially independent, then they were considered independent home-ranges in subsequent analyses. However, if they were not significantly independent then they were combined and analyzed as a single multi-year home-range. All estimated American marten locations were entered into ArcView (Environmental Systems Research Institute, Inc., Redlands, CA, U.S.A.) and Animal Movement extension (Hooge and Eichenlaub, 1997) was used to determine the 95% fixed-kernel home-range and the 50% fixed-kernel (core area) (Worton, 1989) using a least square cross-validation smoothing parameter (Silverman, 1986). A Student's *t*-test (Ott and Longnecker, 2001) was performed to determine if there was a significant difference in home-range size between males and females and between 95% and 50% fixed-kernel home-range estimates.

To determine the area that we effectively sampled (study area) for resident American martens, we buffered all locations where traps were open seven or more consecutive trap-nights by 3.2 kilometers. An examination of past trapping data revealed that more than 90% of the initial captures of American martens occurred within the first 7 d of trapping a particular site. Most subsequent captures at that site were of American martens previously marked (Gilbert, unpubl. data). The buffer distance of 3.2 km was chosen because it was the maximum distance from a capture location to the most distant edge of that individual's 95% fixed-kernel home-range. This corresponds to the best estimate of the distance that the traps will pull in animals and thus which areas were available to the population of martens that we studied.

Forest types were grouped into cover-type categories using U.S. Forest Service (USFS) compartment maps (2001) for the Chequamegon-Nicolet National Forest (Table 1.). Stands and compartment are the timber management units used by the U.S. Forest Service personnel for public lands contained within the Chequamegon-Nicolet National Forest. Areas of private land (17% of the study area) within the study area were not inventoried by means of a timber cruise and thus were assigned to cover-type categories using classified multi-date satellite imagery from the Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WiscLand, 1992). WiscLand classified land cover information from spectral reflectance data obtained from the LANDSAT Thematic Mapper satellite (30 m resolution). WiscLand overall accuracies for forest species were 70% to 84% (Reese *et*

TABLE 1.—Forest-types and corresponding size classes from USDA Forest Service compartment stand data of the Chequamegon-Nicolet National Forest (2001) were assigned to cover-types. The cover-types present in the study area were then reassigned to selection categories (highly used, neutral or avoided) based upon Wright's (1999) habitat selection studies and subsequent research

CDS Forest Type Group	Forest Type	Cover-type Categories	Size Class	Area (km)^2	% Study Area
Selection category: Highly used					
upland mesic hardwoods	sugar maple-yellow birch	upland hardwood	saw	30.53	12.20
	sugar maple-basswood		pole	52.61	21.03
	sugar maple		seed/sapling	0.36	0.14
	red maple				
	mixed northern hardwoods-hemlock				
	mixed hardwoods (maple, basswood, white ash, and birch)				
aspen-birch	quaking aspen	aspen/birch/fir	saw	17.50	6.99
	paper birch				
	big-tooth aspen				
	balsam poplar				
	aspen-whites spruce-balsam fir				
			Total Highly-used	**101.00**	**40.36**
Selection category: Neutral					
lowland hardwood	black ash-red maple	lowland hardwood	saw	0.88	0.35
	red maple (wet)		pole	11.20	4.47
	mixed lowland hardwoods				
conifers	jack pine	upland conifer	saw	3.35	1.34
	red pine		pole	2.83	1.13
	white pine		seed/sapling	1.17	0.47
	white pine-hemlock				
	hemlock				
	balsam fir-aspen				
	balsam fir-aspen				
	white spruce-balsam fir				
	upland black spruce				
			Total Neutral	**19.43**	**7.76**

TABLE 1.—Continued

CDS Forest Type Group	Forest Type	Cover-type Categories	Size Class	Area $(km)^2$	% Study Area
Selection category: Avoided					
lowland hardwood	black ash-red maple	lowland hardwood	seed/sapling	0.77	0.31
	red maple (wet)				
	mixed lowland hardwoods				
conifers	lowland black spruce	lowland conifer	saw	7.62	3.04
	white cedar		pole	12.08	4.83
	mixed swamp conifer		seed/sapling	5.80	2.32
	cedar-aspen				
non-forested	non-forested lowlands (open water lowland brush, bogs, marshes, sedge meadows)	non-forested	n/a	17.82	7.12
	non-forested uplands (upland openings savannahs, and barren land)				
aspen-birch	quaking aspen	aspen/birch/fir	pole	12.84	5.13
	paper birch		seed/sapling	19.61	7.84
	big-tooth aspen				
	balsam poplar				
	aspen-white spruce				
			Total Avoided	**76.54**	**30.59**
water	open water	water	n/a	10.18	4.07
		Total of study area from CDS data.		**207.15 km^2**	**82.78%**

TABLE 2.—Areas of private land within the study area were assigned to cover-types using reclassified multi-date satellite imagery (WiscLand, 1992). The cover-types present in the study area were then reassigned to selection categories (highly used, neutral or avoided) based upon Wright's (1999) habitat selection studies and subsequent research

Forest Type	Cover-type	Area $(km)^2$	% of Study Area
Selection category: Highly used			
northern hardwood	upland hardwood	27.85	11.13
aspen (35%)	aspen/birch/fir	2.43	0.97
	Total	30.28	12.1
Selection category: Neutral			
Lowland hardwood	lowland hardwood	1.18	0.47
balsam fir	upland conifer	1.72	0.69
hemlock			
jack pine			
red pine			
upland spruce			
white pine			
Oak		0.07	0.03
	Total	2.97	1.19
Selection category: Avoided			
aspen (65%)		4.51	1.8
lowland conifer		5.34	2.13
	Total	9.85	3.93
Total of study area from WiscLand satellite imagery:		**43.10(km)2**	**17.22%**

al., 2002). The cover-type categories in the study area then were reassigned to selection categories (highly used, neutral or avoided) based upon Wright's (1999) second-order selection studies (Table 1.). Private land without USFS compartment data was reclassified by WiscLand satellite imagery (Table 2.). However, the WiscLand imagery did not contain size-class information. The only forest types in which selection values varied by size-class was aspen, with the saw-log size-class classified as highly used and the pole and seedling/sapling size classes classified as avoided. The WiscLand aspen forest type represented only 2.8% of the study area and 0.5% of American marten home-ranges. We found that 35% of the aspen on the portion of the study area classified by U.S.F.S. compartment maps (CDS) was in the aspen saw log class (highly used) and 65% was in either the pole or seedling/sapling classes (avoided). For the aspen patches contained on private land without USFS compartment we considered the patch 35% highly used and 65% avoided for analysis. The reclassified highly used, neutral and avoided map then was used for the investigation of landscape-level habitat selection.

The 95% and 50% home-range estimates were over-laid onto the reclassified cover-type map of the study area. The proportions of highly used, neutral and avoided cover-types within each home-range, core area and study area were calculated. A Chi-square test for independence was used to compare average proportions of each selection category between males and females (Neu *et al.*, 1974). If no differences were detected then genders were pooled for subsequent analyses. Proportion of selection categories within home-ranges and core areas were compared against the proportions of each category available in the study area by use of chi-square tests. Another chi-square test was performed on average proportions in each selection category for American marten core areas versus home-ranges. Statistical significance for all tests was accepted at $\alpha = 0.05$.

TABLE 3.—Multi-Response Permutation Procedure test to determine if 4 American marten home-ranges shifted from previous year(s)

	M189	F192	F194	F195
No. Locations Year One		29		
No. Locations Year Two		16	18	
No. Locations Year Three	22			15
No. Locations Year Four	15		20	17
MRPP test statistic	−2.26	0.76	−2.90	−3.77
P-value	0.0380	0.7750	0.0197	0.0032

RESULTS

Twenty-four American martens (14M:10F) were captured from 2001 to 2004. Radio-collared individuals were located 478 times (mean 20 times/animal +/− 5). Of the 478 locations, we discarded those from the 11 animals with <15 locations and those 96 locations where the error ellipse exceeded 0.2 km^2, resulting in 333 locations on 13 American martens available for analysis. The estimated average error associated with azimuth readings for 11 test collars was 12.6 degrees (SD = 10.6°).

Thirteen individual American martens (8M:5F) were classified as resident adults, defined as animals recaptured in same locale over a period of 3 mo or longer (Weckwerth and Hawley, 1962). We estimated home-ranges in multiple years for four of the 13 American martens. MRPP tests of multi-annual location data for American martens M189, F194 and F195 showed that annual patterns of space use were spatially independent of each other (Table 3). Therefore, we treated home-range estimates for these animals from successive years as statistically independent observations in subsequent analysis. MRPP analysis of animal F192′ showed that annual patterns of space use were not independent of each other (Table 3). Location data for animal F192 were combined into a single multi-annual home-range estimate for subsequent analysis. These determinations resulted in 16 home-ranges for further analyses.

The mean 95% fixed-kernel home-range size for males (n = 9) was 4.25 km^2 (SD = 1.04 km^2) and for females (n = 7) was 2.32 km^2 (SD = 0.84 km^2). These two estimates averaged to a value of 3.29 km^2 for the home-range size of American martens in our study area. The mean 50% fixed kernel home-range (core area) size for males was 0.68 km^2 (SD = 0.23 km^2) and for females was 0.38 km^2 (SD = 0.29 km^2). On average, the 95% fixed-kernel home-ranges of males were significantly larger than those of females (t = 2.145, df = 14, P = 0.0014) and the 50% fixed-kernel home-ranges (core areas) of males were significantly larger than those of females (t = 2.145, df = 14, P = 0.0352). A significant difference between the mean size of core and home-range area was found for both sexes combined (t = −8.18, df = 30, P < 0.0001) as well as for males (t = −9.78, df = 16, P < 0.0001) and females (t = −5.73, df = 12, P < 0.0001) independently.

The effective sampling area (called study area) was 250 km^2 (Fig. 1). This study area consisted of 131 km^2 (52%) of highly used habitat comprised of upland hardwood and aspen/birch/fir saw-timber cover-types, 22 km^2 (9%) of neutral habitat comprised of the lowland hardwood and upland conifer cover-types, and 86 km^2 (34%) of avoided habitat comprised of lowland hardwood seedling/sapling, lowland conifer and non-forested cover-types. The study area also contained 10 km^2 (4%) of water that was not classified.

Males and females had similar proportions of highly used, neutral and avoided selection categories in their home-ranges (X^2 = 0.2617, df = 2, P > 0.8773) and, thus, males and females proportion of use estimates were pooled for analyses of habitat selection.

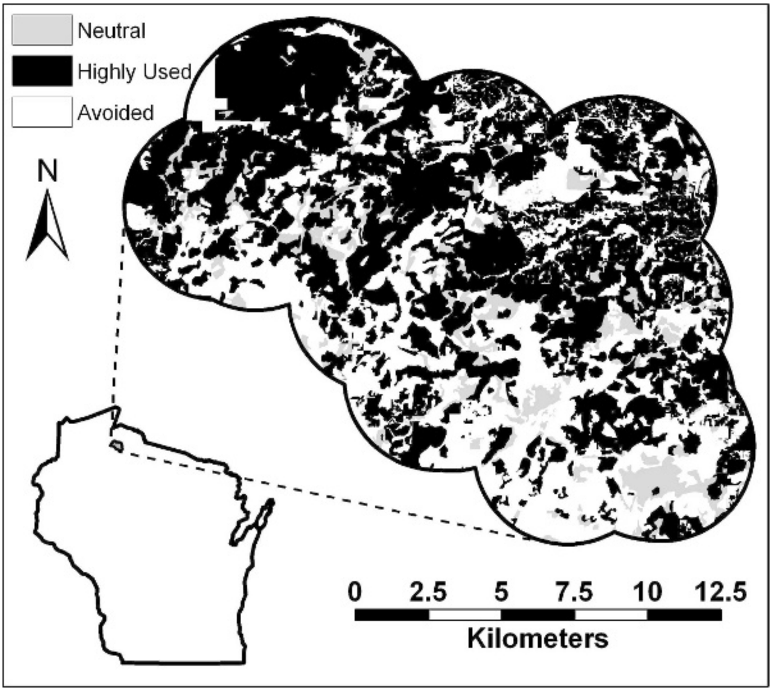

FIG. 1.—Study area located in Wisconsin, U.S.A. Shading indicates the three selection categories: highly used, neutral, and avoided of cover types for American marten within the study area

Proportions of selection categories in home-ranges differed significantly from what was available in the study area ($X^2 = 6.9145$, df = 2, $P > 0.0315$). Bonferroni comparisons indicated that home-ranges contained significantly more highly used (72% versus 57%) and significantly less avoided (18% versus 33%) habitat than expected based on the occurrence of these selection categories within the study area (Table 4). The neutral selection category was used in proportion to its availability. There was no significant difference in selection category proportions between core and study areas ($X^2 = 0.1875$, df = 2, $P > 0.9105$) nor between core areas and home-ranges ($X^2 = 0.1875$, df = 2, $P > 0.9105$) despite the fact that core areas contained more highly used (77%) and less avoided (11%) cover types. This lack of statistical difference can be attributed to the much higher variance of category composition in core areas (*e.g.*, highly used cover SD = 19%) than in home-ranges (*e.g.*, highly used cover SD = 11%).

TABLE 4.—Availability and use of categories by American marten in 95% fixed-kernel home-ranges in northern Wisconsin

			Bonferroni Confidence Intervals		
Category	Study Area Proportion	Home-range Proportion	Lower 95% Confidence Interval	Upper 95% confidence Interval	Significance (a = 0.05)
Avoided	0.3379	0.1885	0.0610	0.3161	Less use
Neutral	0.0933	0.0944	−0.0009	0.1898	
Highly used	0.5689	0.7170	0.5702	0.8639	More use

DISCUSSION

Little has been published on the ecology of the American marten in Wisconsin despite the species' status within the state and region. Our results fill an important gap in understanding habitat selection by American marten in Wisconsin. Earlier work by Wright (1999) with a population of American marten on the Nicolet section of the Chequamegon-Nicolet National Forest, reported stand-level habitat selection patterns based upon telemetry locations of individual American martens. In this study, we use cover-type selection categories derived from Wright's (1999) point-based habitat selection study and examined habitat selection at the scale of home-range. This scaled-up examination of habitat selection adds to our understanding of the hierarchical nature of habitat selection by American marten in Wisconsin by providing a bridge between analysis of point locations and home-ranges.

The three cover-type selection categories that we extracted from Wright's (1999) analysis performed very well in distinguishing habitat selection at the level of a home-range in our study area. Our observation that American martens establish home-ranges that contain significantly more highly used cover-types (*e.g.*, mature upland hardwoods), and less avoided cover-types (*e.g.*, non-forested, lowland conifers and small size classes of aspen and lowland hardwood types) is consistent with work on American marten in other areas where they face similar conditions (Chapin *et al.*, 1997; Potvin *et al.*, 2000; Fuller and Harrison, 2005). Moreover, our results support observations from across the American marten's geographic range (Thompson and Harestad, 1994; Bissonette *et al.*, 1997; Hargis and Bissonette, 1997; Chapin *et al.*, 1998; Potvin *et al.*, 2000) that American martens establish home-ranges in areas that contain at least 70% of suitable cover-types (Table 4). From this we can infer that American martens in northern Wisconsin face landscape-level constraints on their home-range selection patterns similar to American martens elsewhere. Those areas within Wisconsin where the proportion of suitable habitat is less than this threshold are not likely to support American marten populations.

Our results suggest that, based upon the current level of CDS data, home-range establishment is better predicted by broad cover-type categories of highly used, neutral and avoided than are core areas or activity centers. The significant difference in cover-type composition of home-ranges relative to availability within the study area demonstrates the occurrence of selection at the home-range scale. In contrast, core areas had a higher average proportion of highly used cover-types than either home-ranges or the study area, but because the variance around this average was large the cover-type composition of core areas was statistically indistinguishable from both home-ranges and the study area. Furthermore, the observation that core areas were significantly smaller than home-ranges suggests that core areas contain micro-site feature(s) that caused numerous telemetry locations to occur in close proximity to each other. These high densities of telemetry locations may correspond to microhabitat features, such as winter resting sites and prey populations, which have been shown to be necessary aspects of American marten habitat at finer spatial scales (Buskirk *et al.*, 1989; Gilbert *et al.*, 1997; Ruggiero *et al.*, 1998). Taken together, the small relative size of the core areas as well as the extreme variance in their proportional cover-type composition suggest that at the core area scale the three broad cover-type categories that we examined are at best weakly correlated with features American martens are selecting. The significance of these cover-types to habitat selection at the coarser spatial scale of a home-range, but not at the finer spatial scale of the core area, is consistent with the idea that American martens select habitat based upon a hierarchical process that emphasizes different features at different spatial scales (Johnson, 1980; Potvin *et al.*, 2000). Future research should identify and measure these finer spatial scales characteristics for marten in Wisconsin.

Our estimates of average size of winter home-ranges for the Chequamegon population of American martens were similar to those reported by Wright (1999) for the Nicolet population of American martens. Estimates of average size of winter home-ranges from both of these studies in the deciduous-dominated forests of northern Wisconsin are on the smaller end of home-range sizes for American martens across their geographic range (*see* reviews by Strickland and Douglass, 1987 and Powel, 1994). However, exact comparison of home-range size with other studies is problematic because of differences in the collection of telemetry observations (*e.g.*, duration and season of study) as well as differences in the techniques used to estimate home-ranges (*e.g.*, minimum convex polygon or kernel estimators) (Strickland and Douglass, 1987; Powel, 1994; Buskirk and McDonald, 1989). Nonetheless, the consistency in home-range size estimates between these two studies suggests that male American martens in Wisconsin on average require a little more than 4 km^2 to establish a home-range and that females on average require a little over 2 km^2 with the upper 95% confidence interval for female home-ranges corresponding to the average male home-range size of slightly greater than 4 km^2. The convergence of the average male minimum area requirement with the upper bound on that value for females suggests that management efforts for marten in Wisconsin should conservatively consider that only areas with at least 2.8 km^2 of non-avoided cover-types (70% of 4 km^2) will provide opportunities for home-range establishment by breeding pairs of marten.

Wildlife management agencies in northern Wisconsin and throughout the upper Great Lakes region can use our results to improve their habitat and population management programs. First, the consistency of our winter home-range size estimates with those of Wright (1999) suggest that in this part of their range American martens require approximately 4 km^2 to establish a winter home-range, thus this should be considered the minimum necessary spatial scale for American marten management. Second, our documentation that Wisconsin American marten establish winter home-ranges in areas where the surrounding 4 square kilometers contain on average at least 70% highly used cover-types suggests that similar to elsewhere within this species range (Bissonette *et al.*, 1997; Chapin *et al.*, 1998; Potvin *et al.*, 2000) this is an important threshold in determining the potential suitability of home-ranges, thus managers should focus their efforts where the landscape configuration meets this criterion. Understanding where such suitable landscape configurations presently exist in this region (Zollner *et al., In press*) and how forest management can facilitate the development of more areas with these conditions are important future research directions (Zollner *et al., In press*). Third, the hierarchical nature of habitat selection leads to the caveat that areas identified as suitable for American marten home-range establishment at the landscape scale using cover-type selection categories also must provide micro-site requirements such as den and rest site features and adequate prey populations. Sites identified as suitable based on cover-types may not be occupied by American martens if these site specific features are missing. These insights into American marten habitat selection ecology within Wisconsin are important for improving management of this species throughout the upper Great Lakes region.

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