Modeling of Wildlife Dispersal Habitat at Stevens Pass, Washington

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Overview

The connectivity of habitats for wildlife is of increasing conservation concern (Crooks and Sanjayan 2006, Hilty et al. 2006). Advances in the scientific understanding of species movement and dispersal, along with GIS analytical tools, now permit habitat connectivity to be rigorously evaluated (Singleton et al. 2002, McRae et al. 2007). The greater Stevens Pass region along Highway 2 in Washington State provides an important north-south connection for many wildlife species (Singleton et al. 2002). Thus, initial scoping for proposed projects related to the Stevens Pass Ski Area identified habitat connectivity as an important issue to evaluate. The objective of this modeling exercise was to develop “existing conditions” dispersal models for the following four focal wildlife species: grizzly bears (*Ursus arctos*), Canada lynx (*Lynx Canadensis*), wolverines (*Gulo gulo*), and American martens (*Martes americana*). These models can be used to evaluate the potential effects of proposed land-use changes on wildlife dispersal habitat in the Stevens Pass region. We chose to specifically model dispersal habitat —as opposed to “core” or “source” habitat— because of the specific interest in ultimately using the model to evaluate the effects of land-use change on wildlife habitat permeability or connectivity. Models focused on wildlife movement (e.g., dispersal, range shifts), therefore, are most appropriate. For each species, we also built a baseline model that excluded direct anthropogenic effects (i.e., roads, trails, houses/buildings). These were deemed “baseline” models.

Dispersal habitat models were created using a GIS approach that will be useful in evaluating the effects of various land-use changes on wildlife dispersal habitat throughout the project area. A scientific review team consisting of resource managers, consultants, and members of the NGO community (see Appendix A) was assembled to: (1) review and select appropriate modeling methods; (2) identify appropriate GIS data for analysis; (3) assign species-specific permeability values to GIS layer attributes; and (4) review model outputs. The outcome includes maps and GIS grid files that depict the ease with which focal species would be predicted to disperse through any particular grid cell within the modeled extent—expressed as “dispersal habitat suitability.” Dispersal habitat suitability at any given grid cell is calculated as the product of the permeability values for all layers at that cell, and is interpreted as the cumulative effect of all variable inputs at that cell. Our models assessed only dispersal habitat and not core or source habitat for each species. Alternative and complementary modeling approaches (e.g., cost-weighted distance, least-cost corridor, circuit theory) building on the results of our effort may be applied by other researchers or interested parties to further evaluate habitat connectivity, or to assess the effects of various management decisions on dispersal habitat.

Methods

We applied dispersal modeling methods similar to those used by Singleton et al. (2002) and Gaines et al. (in preparation) to the region surrounding the Stevens Pass Ski Area. The spatial extent of the assessment was delineated by the scientific review team and included 19 6th-field watersheds in both the Wenatchee/Okanogan (Oka-Wen) and Mount Baker/Snoqualmie (MBS) National Forests (Fig. 1). GIS layers used in the various models included elevation, slope, vegetation zones, current vegetation structure (i.e., land cover), roads, trails, and house/building locations. Elevation, slope, vegetation zones, trails, and roads layers were obtained from the Oka-Wen and MBS databases, clipped to the analysis extent, and merged into seamless layers.

GIS layers representing current vegetation height and current vegetation cover were obtained from the LANDFIRE (Landscape Fire and Resource Management Planning Tools Project) national database (http://www.landfire.gov). The house/building layer was manually digitized with the aid of digital 7.5 minute USGS quadrangle maps and aerial photographs. Detailed road, trail, and building location data within the Stevens Pass Resort (Fig. 2) were provided by Tetra Tech EC, Inc (Bothell, Washington). All GIS data were analyzed in raster format with a 30-m cell size using ArcGIS 9 software and the ModelBuilder application (ESRI, Redlands, California, USA).

We developed a land cover layer by combining and reclassifying the two LANDFIRE datasets into 16 different landscape categories (see Table 1). Roads within the analysis extent were broken into four classes based on road type: (1) highways; (2) small highways; (3) secondary roads; and (4) forest roads. Distance allocations (i.e., buffers) generated from each road type resulted in four individual datasets used for modeling road effects. Buffer distances and permeability values were species-specific and based on literature review and expert input from the scientific review team. Distance allocations were also performed on trails and building locations, resulting in two individual datasets used for modeling these variables.

The various attributes of each layer (see Tables 1-7) were assigned permeability values ranging from 0.1 (i.e., low permeability or high cost of movement) to 1.0 (i.e., high permeability or low cost of movement) for each focal species based on literature review and the expert opinion of the scientific review team. All layers were then multiplied together, resulting in an output grid or map where each cell contained an overall permeability score ranging from 0 (low permeability) to 1.0 (high permeability) for each focal species (Figs. 3-18). We classified permeability values into three classes for each species (<0.1 = low; 0.1–0.5 = moderate; >0.5 = high) to facilitate the interpretation and application of model results. Habitat connectivity models were also developed to represent "baseline" scenarios in which direct human influences (i.e., roads, trails, house/building locations) were absent (Figs. 19-26). The outputs from these models represent a type of baseline or historical condition that can be compared with existing conditions or those predicted to occur in the future. Acreages of existing and baseline dispersal habitat identified by the models are summarized in Table 8.

Considerations

This modeling exercise was conducted using standard methods and data inputs, and for species with fairly well-studied habitat requirements. It is still necessary, however, to identify important considerations, assumptions, and caveats that went into the creation of these dispersal models.

- Carnivores were chosen as the focal taxonomic group for this exercise because this group tends to be sensitive to human disturbance and have large spatial requirements. Carnivores are therefore ideally suited for evaluating landscape permeability at large extents and coarse scales. Other groups (e.g., lower mobility species, species with narrow environmental requirements) may be better suited to exploring more fine-grained questions of habitat connectivity and the effects of land-use change and development.

- Certain landscape permeability values were adjusted based on their distribution within the analysis extent and/or their interactions with other layers:

    1. The “shrub cover” attribute in the “Land Cover” layer for the wolverine model was assigned a permeability value of 1.0, as most of the shrub component was located in alpine and parkland areas and such areas are considered to be the best wolverine habitat within the analysis area.

    2. The “developed” attribute within the “Land Cover” layer, while present in the models, was given a permeability value of 1.0 because we had already addressed the influence of anthropogenic factors via the inclusion of the “distance to buildings,” “distance to roads,” and “distance to trails” layers.

- We found it necessary to manually reclassify the permeability values within some distance allocations associated with roads. This was a result of overlapping distance buffers associated with different road classes. For example, a highway with an assigned permeability value of 0.3 and a forest road with an assigned value of 0.6 have an overlap value of 0.3 x 0.6 = 0.18. In this scenario, the 0.18 value must be reclassified to 0.3 to accurately represent the influence of the highway within this region of overlap.

- One of the most important points to consider when reviewing or using the results of this exercise is that the outputs from the models (i.e., permeability values) do not represent permeability *rates*. Instead they are *relative* values designed to either compare between locations, species, times, or scenarios (e.g., pre- and post-manipulation). Thus, while it is valid to say that permeability at a location is higher for one species than another, or higher before a new road was built than after, it is not valid to imply that a given grid cell has a sufficient permeability to permit dispersal with a certain rate, or success.

- The dispersal habitat suitability maps and GIS grids for each species can be used to evaluate management alternatives that affect attributes represented by the input layers. Our goal in developing these models was to provide an objective tool for managers to evaluate the effects of various types, locations, and intensities of land use on wildlife dispersal habitat. This report, therefore, intentionally refrains from interpreting model results, or from discussing potential management implications.

References

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Gaines, W.L., J.S. Begley, B.C. Wales, L.H. Suring, K. Mellen-Mclean, and S. Mohoric. In prep. Terrestrial species sustainability assessments for the national forests in northeastern Washington. USDA Forest Service, PNW-GTR-XXX.

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Table 1. Land cover layer categories and associated species-specific permeability values. "Grid Value" is included primarily for users of accompanying GIS input grid layers.

Landscape Categories	Grid Value	Marten	Wolverine	Lynx	Grizzly
Open Water	1	0.1	0.1	0.1	0.1
Snow/Ice	2	0.1	0.8	0.1	0.1
Developed	3	1.0	1.0	1.0	1.0
Barren/Sparse Vegetation	4	0.1	0.8	0.4	0.4
Agriculture	5	0.1	0.3	0.3	0.3
Shrub	6	0.1	1.0	0.8	0.8
Herbacous	7	0.1	1.0	0.6	0.8
Tree Cover 10-40% and <10m	8	0.1	1.0	1.0	1.0
Tree Cover 40-70% and <10m	9	0.1	1.0	1.0	1.0
Tree Cover >70% and <10m	10	0.1	0.8	1.0	1.0
Tree Cover 10-40% and 10-25m	11	0.3	1.0	1.0	1.0
Tree Cover 40-70% and 10-25m	12	0.6	1.0	1.0	1.0
Tree Cover >70% and 10-25m	13	0.8	1.0	1.0	1.0
Tree Cover 10-40% and >25m	14	0.3	1.0	1.0	1.0
Tree Cover 40-70% and >25m	15	0.8	1.0	1.0	1.0
Tree Cover >70% and >25m	16	1.0	1.0	1.0	1.0

Table 2. Vegetation zone (i.e., potential vegetation) categories and associated species-specific permeability values. "Grid Value" is included primarily for users of accompanying GIS input grid layers.

Landscape Categories	Grid Value	Marten	Wolverine	Lynx	Grizzly
Shrub steppe	5	0.1	0.5	0.3	0.5
Ponderosa pine	10	0.3	0.5	0.5	0.5
Douglas-fir	14	0.8	1.0	1.0	1.0
Grand fir	16	1.0	1.0	1.0	1.0
Western hemlock	19	1.0	1.0	1.0	1.0
Silver fir	22	1.0	1.0	1.0	1.0
Mountain hemlock	23	1.0	1.0	1.0	1.0
Subalpine fir	25	1.0	1.0	1.0	1.0
Parkland	32	0.8	1.0	0.8	1.0
Alpine	33	0.8	1.0	0.8	1.0

Table 3. Elevation groupings and associated species-specific permeability values.

Elevation (meters)	Marten	Wolverine	Lynx	Grizzly
0-1000	0.6	0.6	1.0	1.0
1000-1500	8.0	8.0	1.0	1.0
1500-2000	1.0	1.0	1.0	1.0
>2000	1.0	1.0	1.0	1.0

Table 4. Slope groupings and associated species-specific permeability values.

Slope (degrees)	Marten	Wolverine	Lynx	Grizzly
0-20	1.0	1.0	1.0	1.0
20-40	1.0	1.0	0.8	1.0
>40	1.0	1.0	0.6	1.0

Table 5. Species-specific trail buffer distances and permeability values.

Focal Species	Buffer Distance (meters)	Value
Marten	100	0.8
Wolverine	100	0.6
Lynx	100	0.6
Grizzly	500	0.5

Table 6. Species-specific building buffer distances and permeability values.

Focal Species	Buffer Distance (meters)	Value
Marten	150	0.8
Wolverine	150	0.6
Lynx	150	0.6
Grizzly	150	0.4

Table 7. Species-specific road buffer distances and permeability values.

Highways

Focal Species	Buffer Distance (meters)	Value
Marten	200	0.3
Wolverine	200	0.3
Lynx	200	0.3
Grizzly	500	0.3

Small Highways

Focal Species	Buffer Distance (meters)	Value
Marten	200	0.4
Wolverine	200	0.4
Lynx	200	0.4
Grizzly	500	0.3

Secondary Roads

Focal Species	Buffer Distance (meters)	Value
Marten	200	0.4
Wolverine	200	0.4
Lynx	200	0.4
Grizzly	500	0.3

Forest Roads

Focal Species	Buffer Distance (meters)	Value
Marten	200	0.8
Wolverine	200	0.6
Lynx	200	0.6
Grizzly	500	0.5

Table 8. Modeling results showing acreages of existing and baseline dispersal habitat, by species and habitat ranking categories, within the analysis area and Stevens Pass Ski Area.

Acres of Existing Dispersal Habitat Rankings within the Analysis Area (618,752 Acres)

Species	High	Moderate	Low
Grizzly Bear	281,412 (45%)	330,878 (53%)	6,462 (1%)
Lynx	458,482 (74%)	151,655 (25%)	8,615 (1%)
Marten	261,020 (42%)	241,985 (39%)	115,747 (19%)
Wolverine	490,435 (79%)	122,083 (20%)	6,234 (1%)

Acres of Baseline Dispersal Habitat Rankings within the Analysis Area (618,752 Acres)

Species	High	Moderate	Low
Grizzly Bear	586,610 (95%)	32,140 (5%)	1 (0%)
Lynx	458,226 (74%)	151,544 (24%)	8,981 (1%)
Marten	272,945 (44%)	237,008 (38%)	108,799 (18%)
Wolverine	610,182 (99%)	3,471 (1%)	5,100 (1%)

Acres of Exisiting Dispersal Habitat Rankings within the Stevens Pass Resort (2,326 Acres)

Species	High	Moderate	Low
Grizzly Bear	106 (5%)	2,193 (94%)	27 (1%)
Lynx	1,081 (46%)	1,239 (53%)	5 (0%)
Marten	869 (37%)	834 (36%)	623 (27%)
Wolverine	1,092 (47%)	1,230 (53%)	4 (0%)

Acres of Baseline Dispersal Habitat Rankings within the Stevens Pass Resort (2,326 Acres)

Species	High	Moderate	Low
Grizzly Bear	2,289 (98%)	36 (2%)	0 (0%)
Lynx	2,147 (92%)	175 (8%)	3 (0%)
Marten	1,156 (50%)	573 (25%)	597 (26%)
Wolverine	2,322 (100%)	0 (0%)	4 (0%)

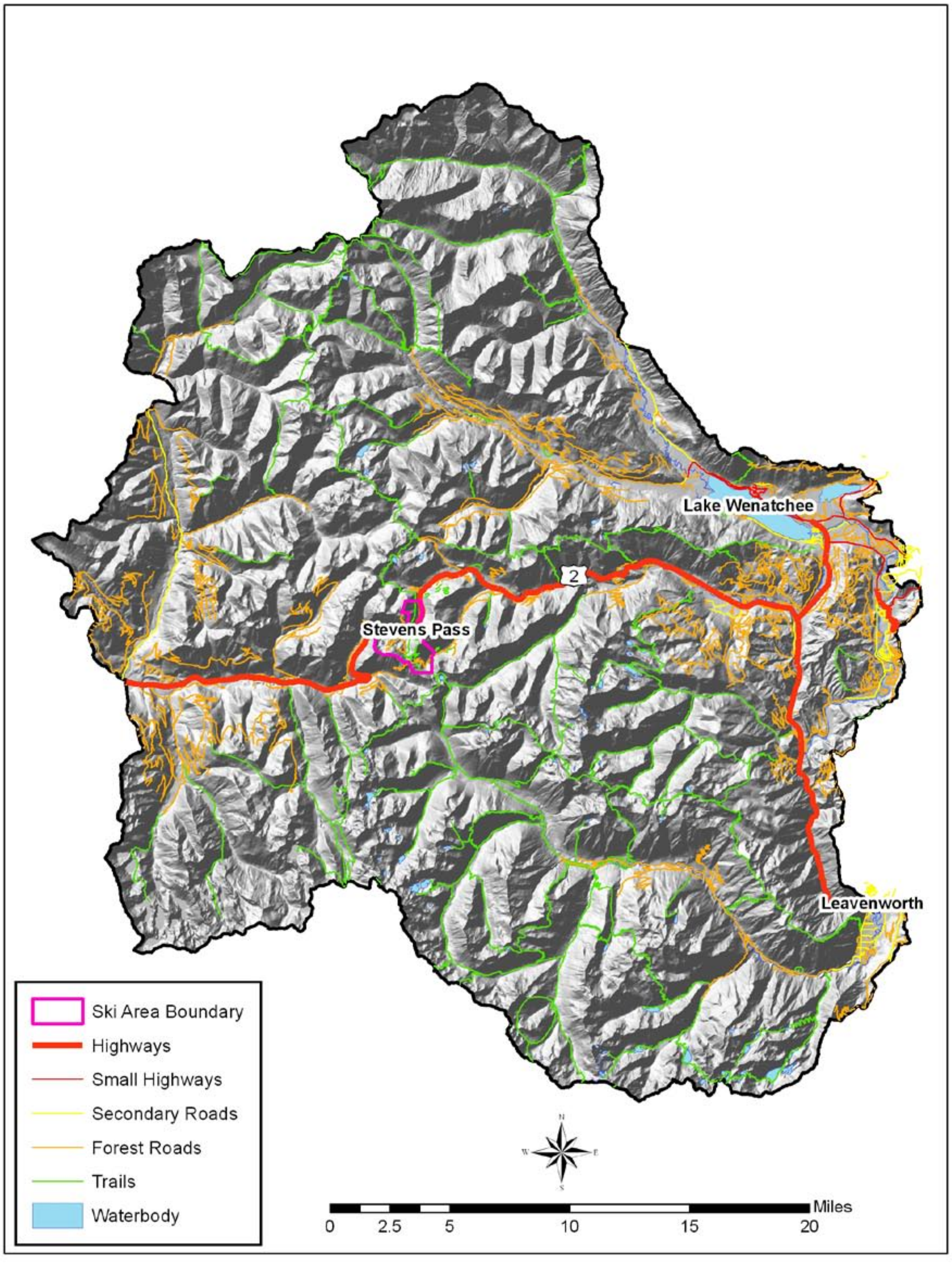

Figure 1. Map of modeling extent (including all or part of 19 6th-field watersheds in both the Wenatchee/Okanogan and Mount Baker/Snoqualmie National Forests), roads, and water bodies.

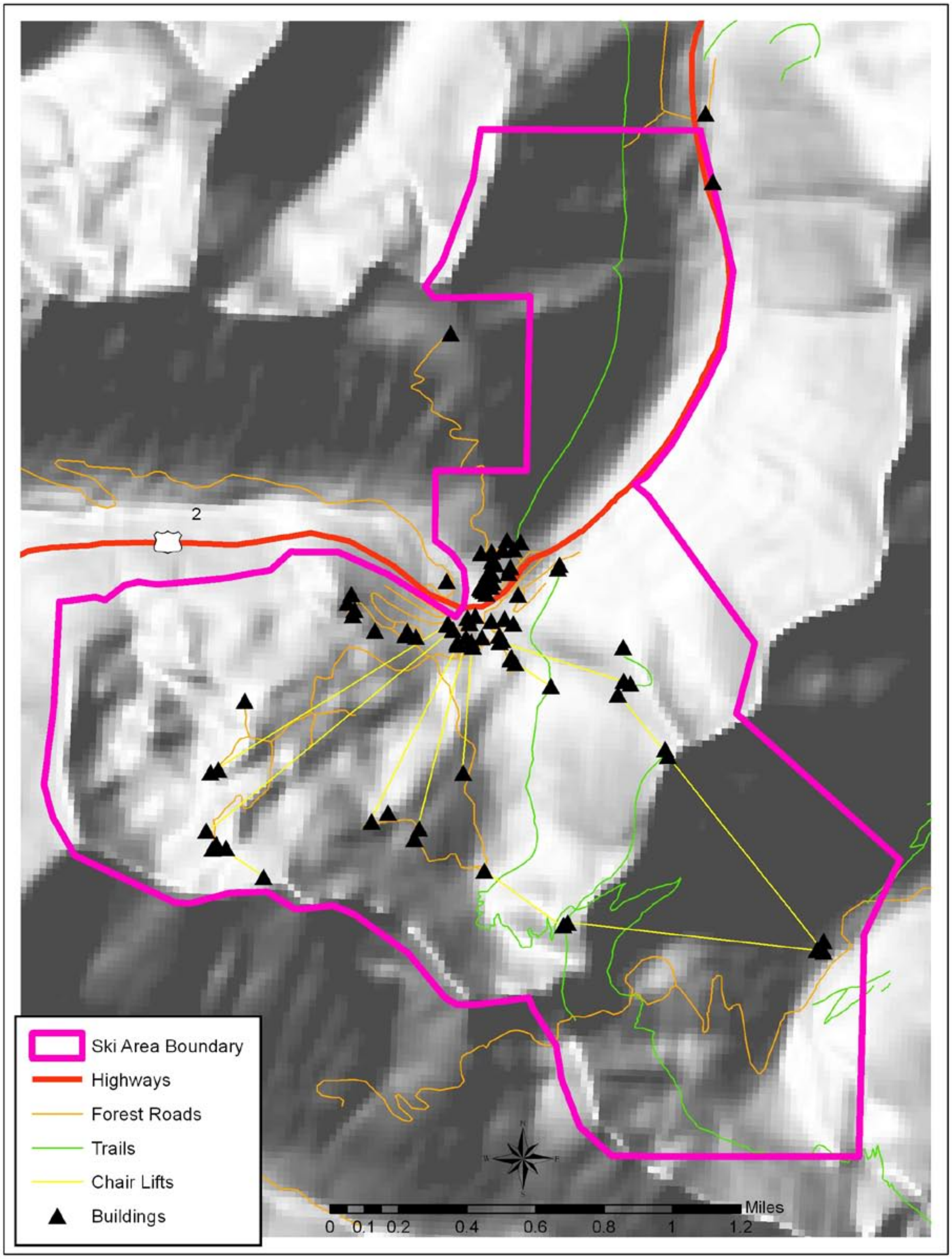

Figure 2. Stevens Pass Ski Area including roads, chair lifts, and buildings.

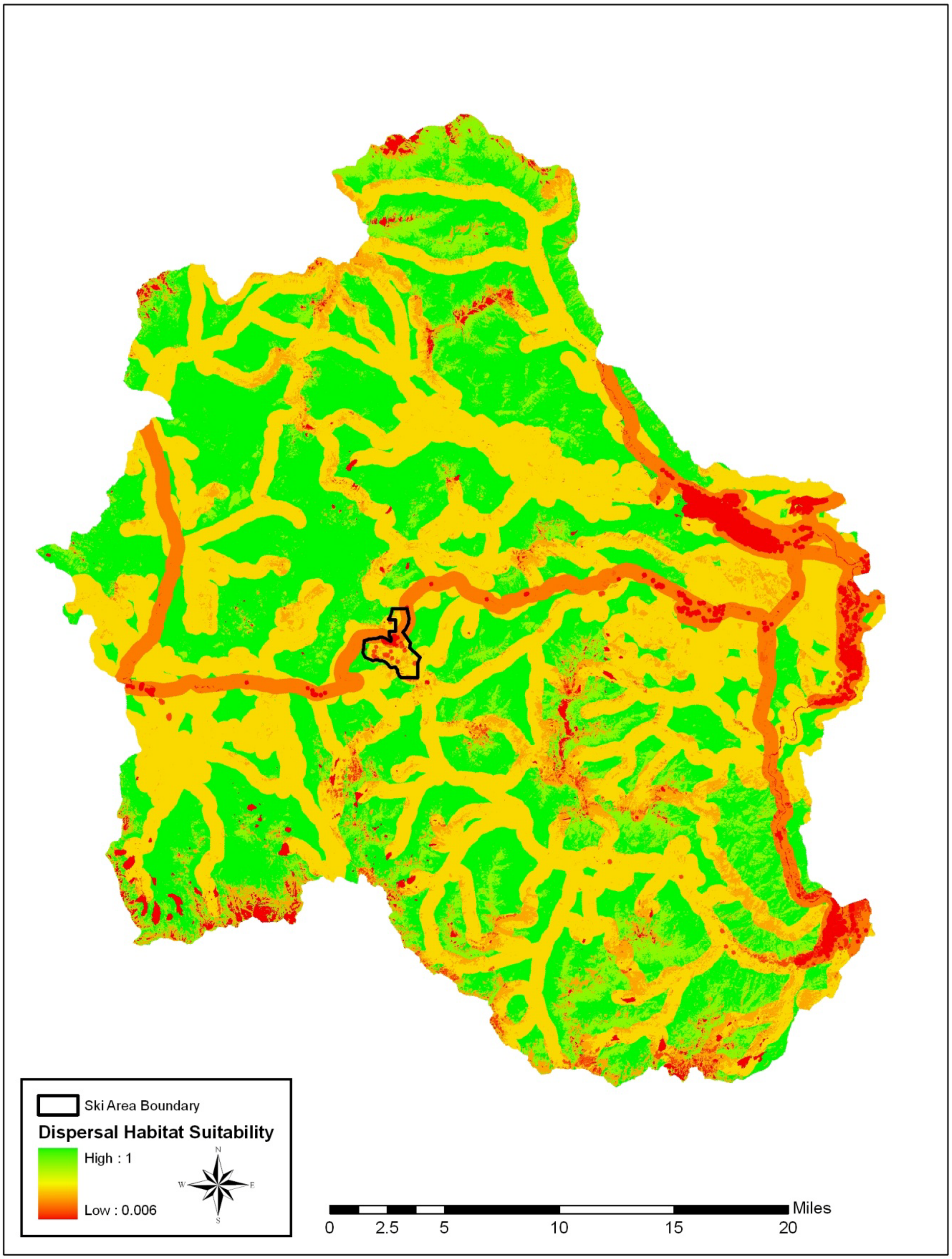

Figure 3. Grizzly bear "existing condition" dispersal habitat suitability for modeling extent.

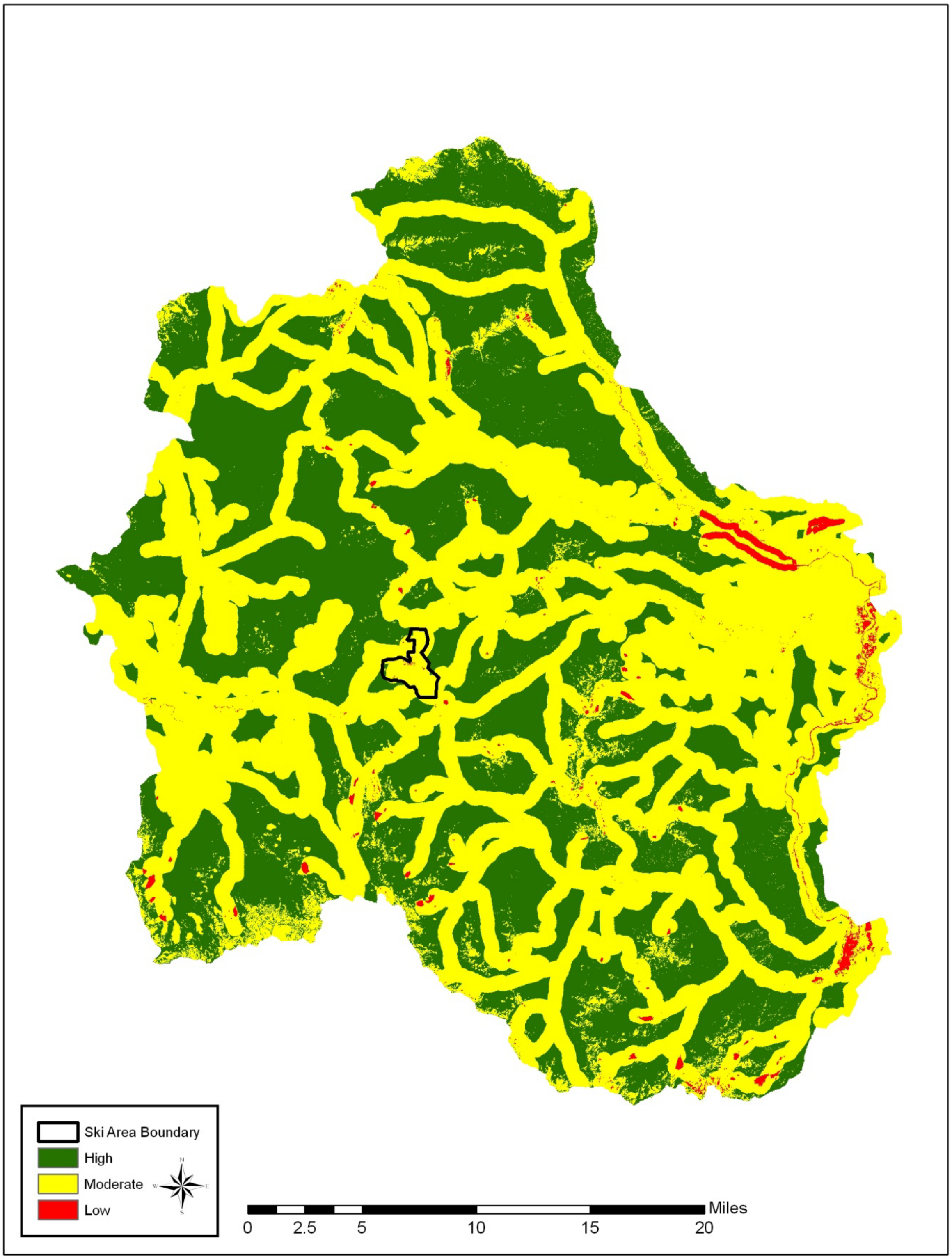

Figure 4. Grizzly bear “existing condition” dispersal habitat suitability for modeling extent with categorical grouping.

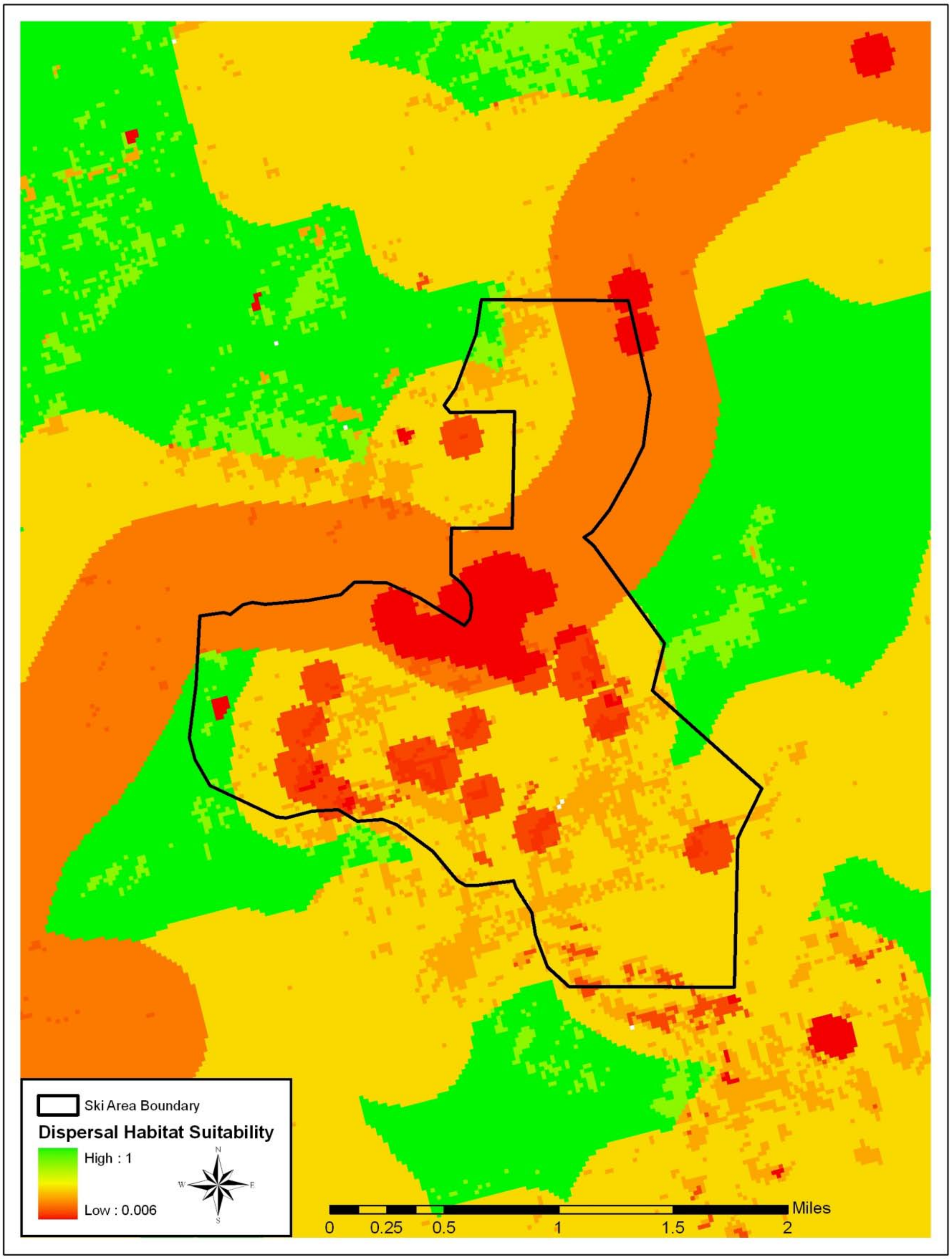

Figure 5. Grizzly bear "existing condition" dispersal habitat suitability for Stevens Pass Ski Area vicinity.

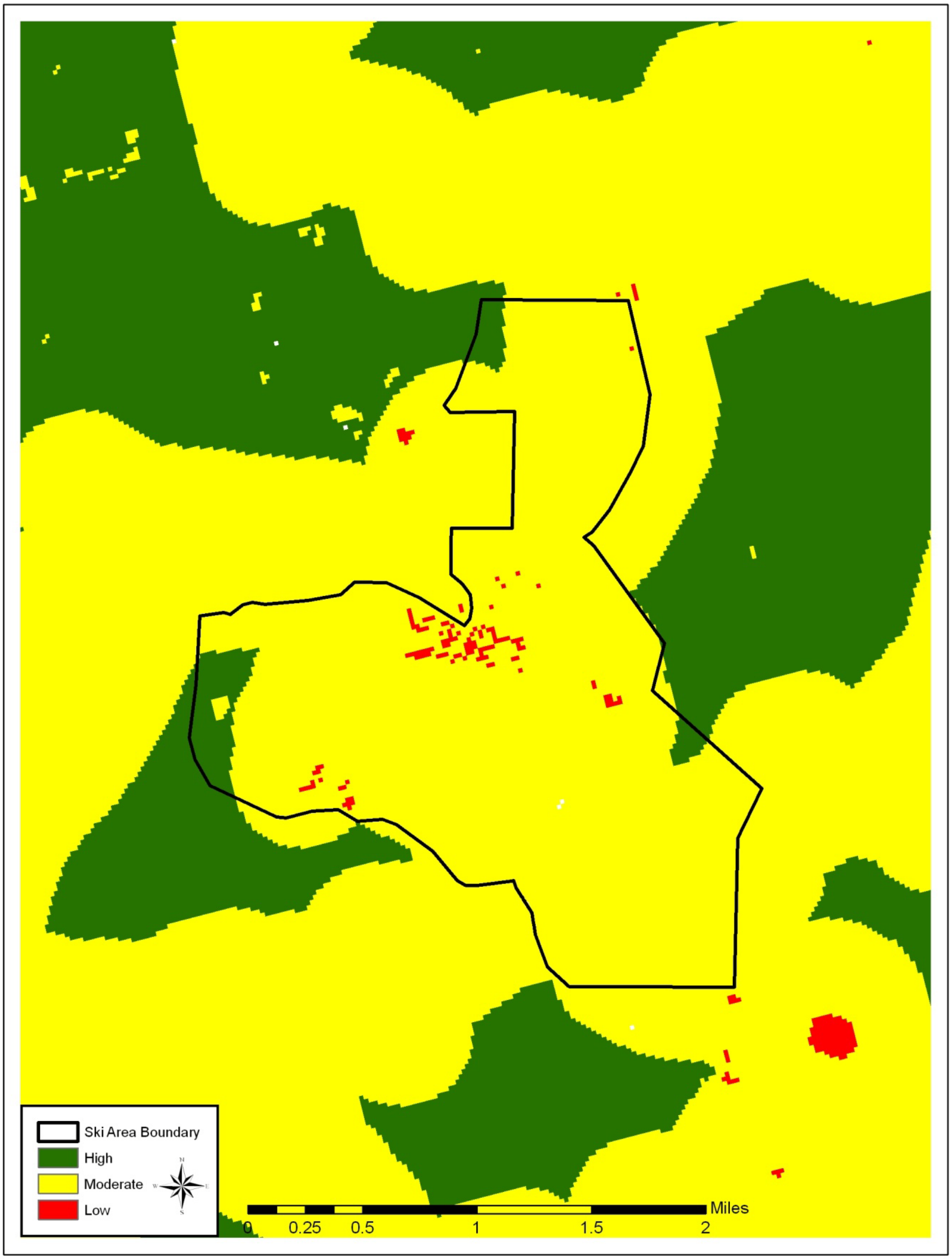

Figure 6. Grizzly bear “existing condition” dispersal habitat suitability, grouped into “high,” “moderate,” and “low,” for Stevens Pass Ski Area vicinity.

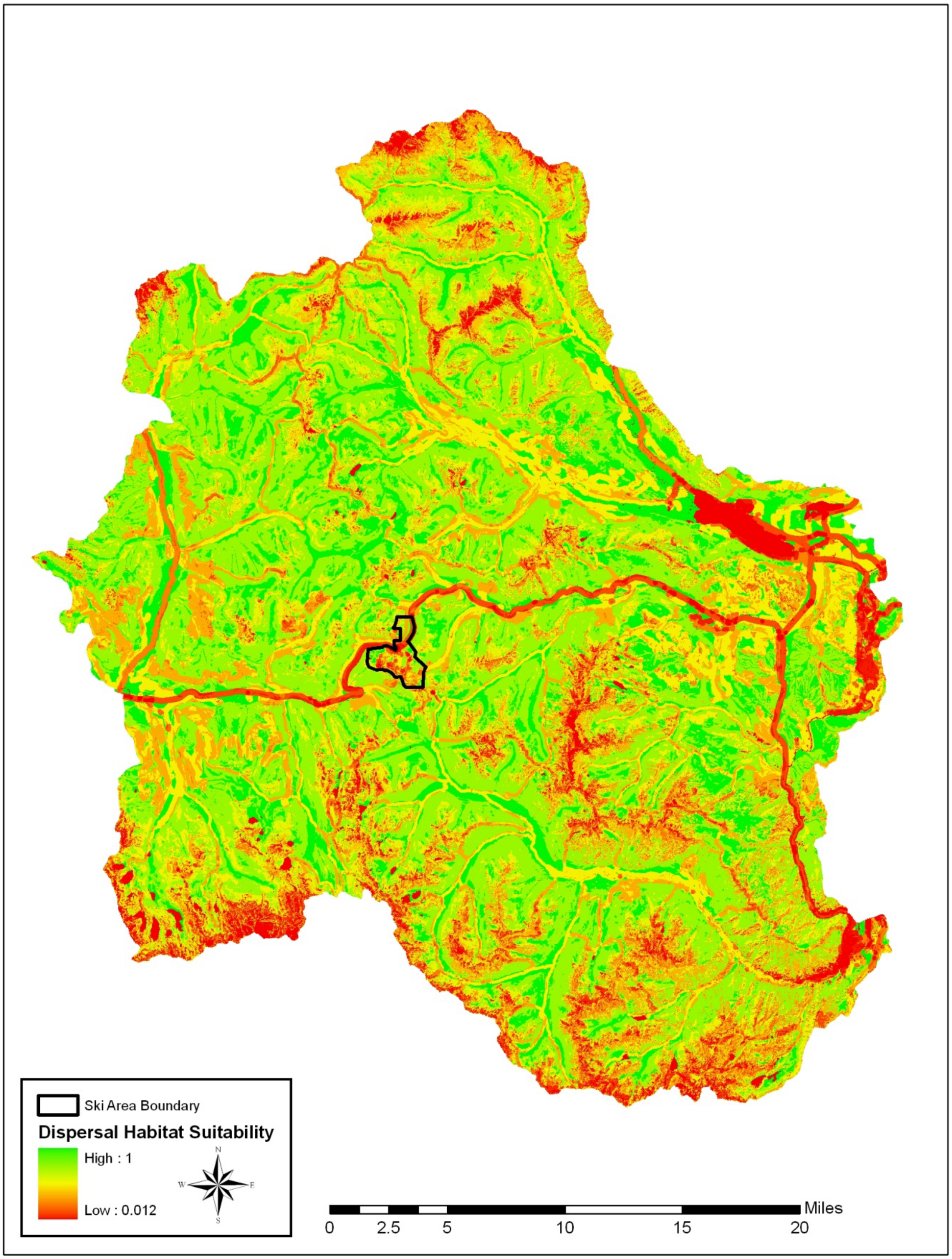

Figure 7. Canada lynx "existing condition" dispersal habitat suitability for modeling extent.

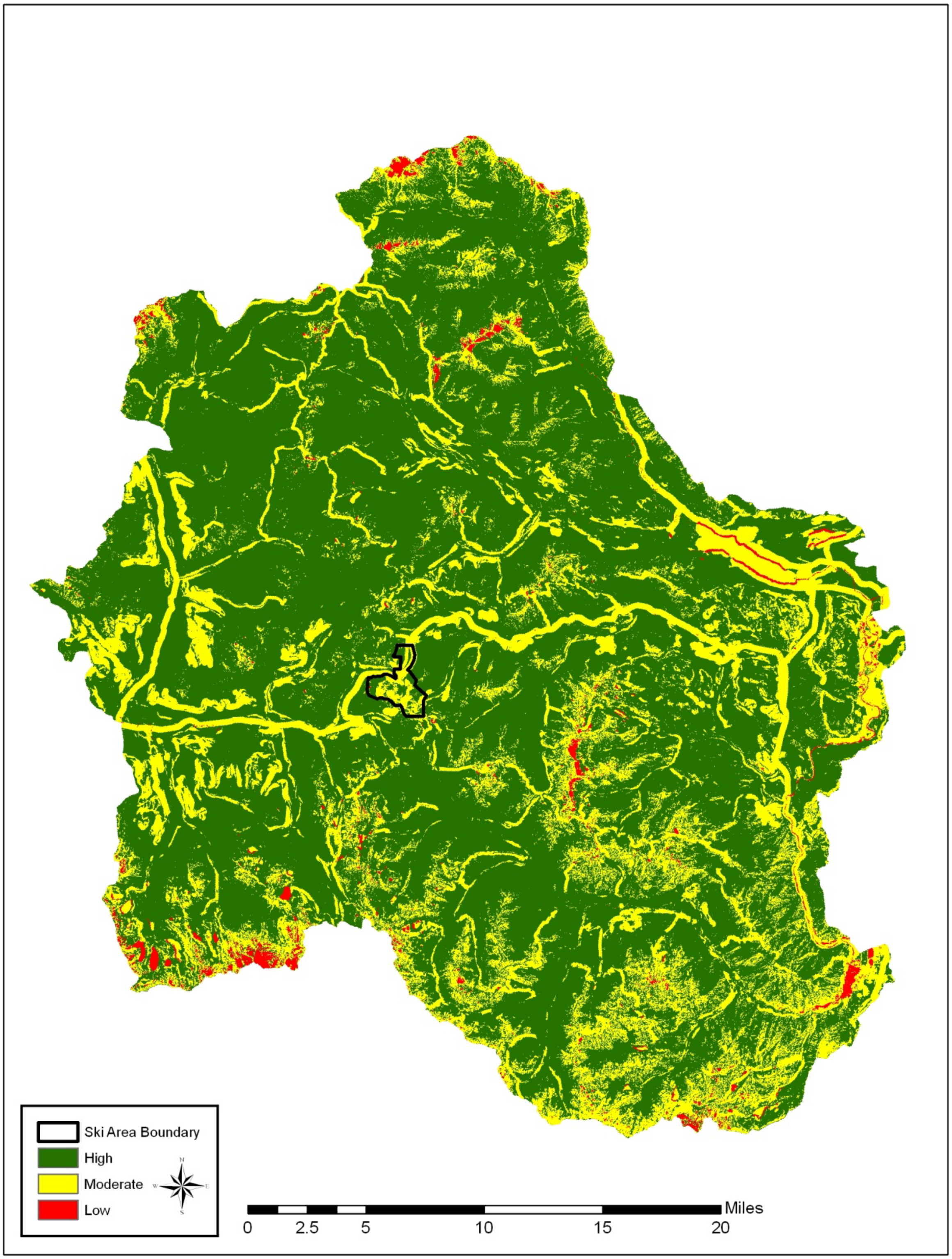

Figure 8. Canada lynx "existing condition" dispersal habitat suitability for modeling extent with categorical grouping.

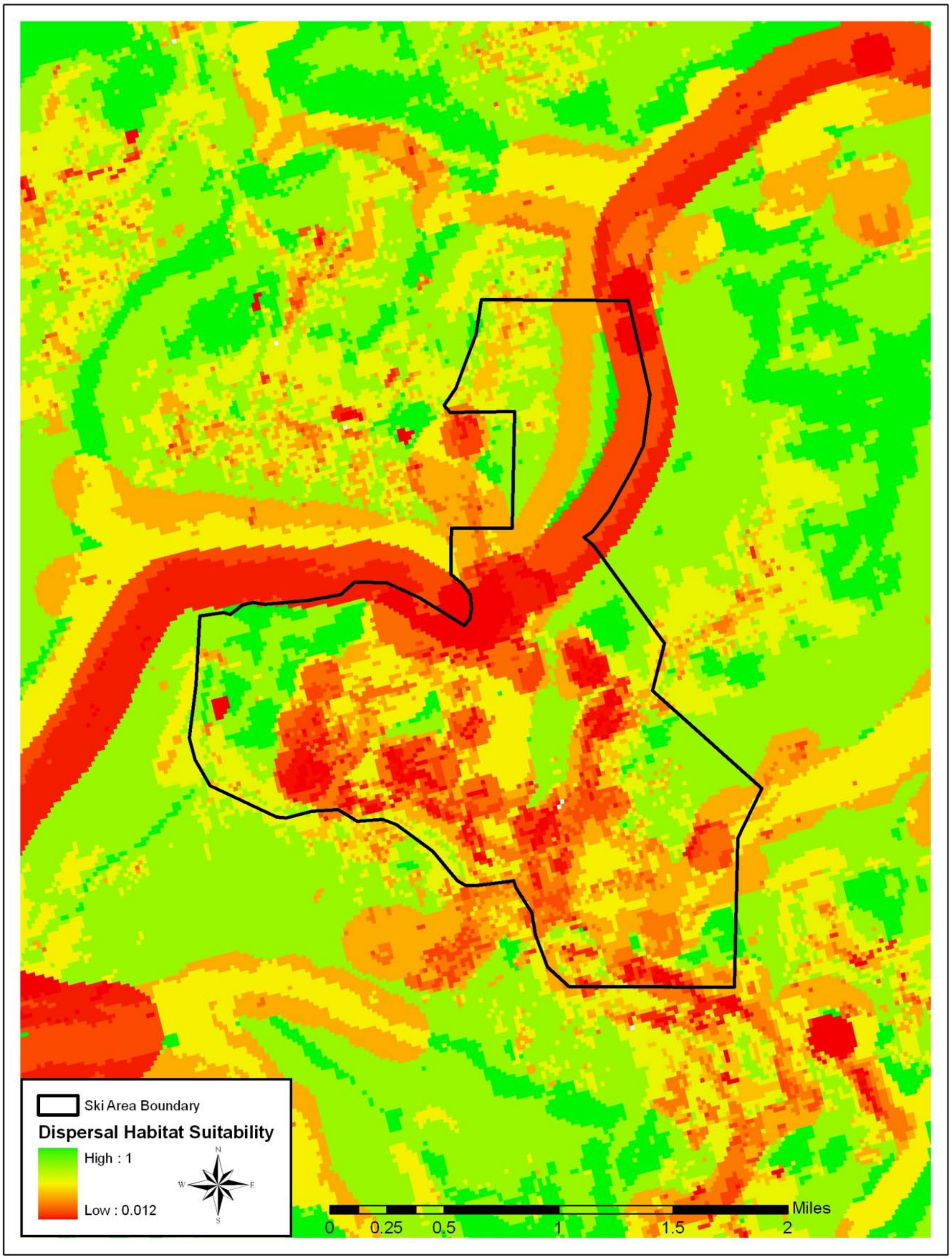

Figure 9. Canada lynx “existing condition” dispersal habitat suitability for Stevens Pass Ski Area vicinity.

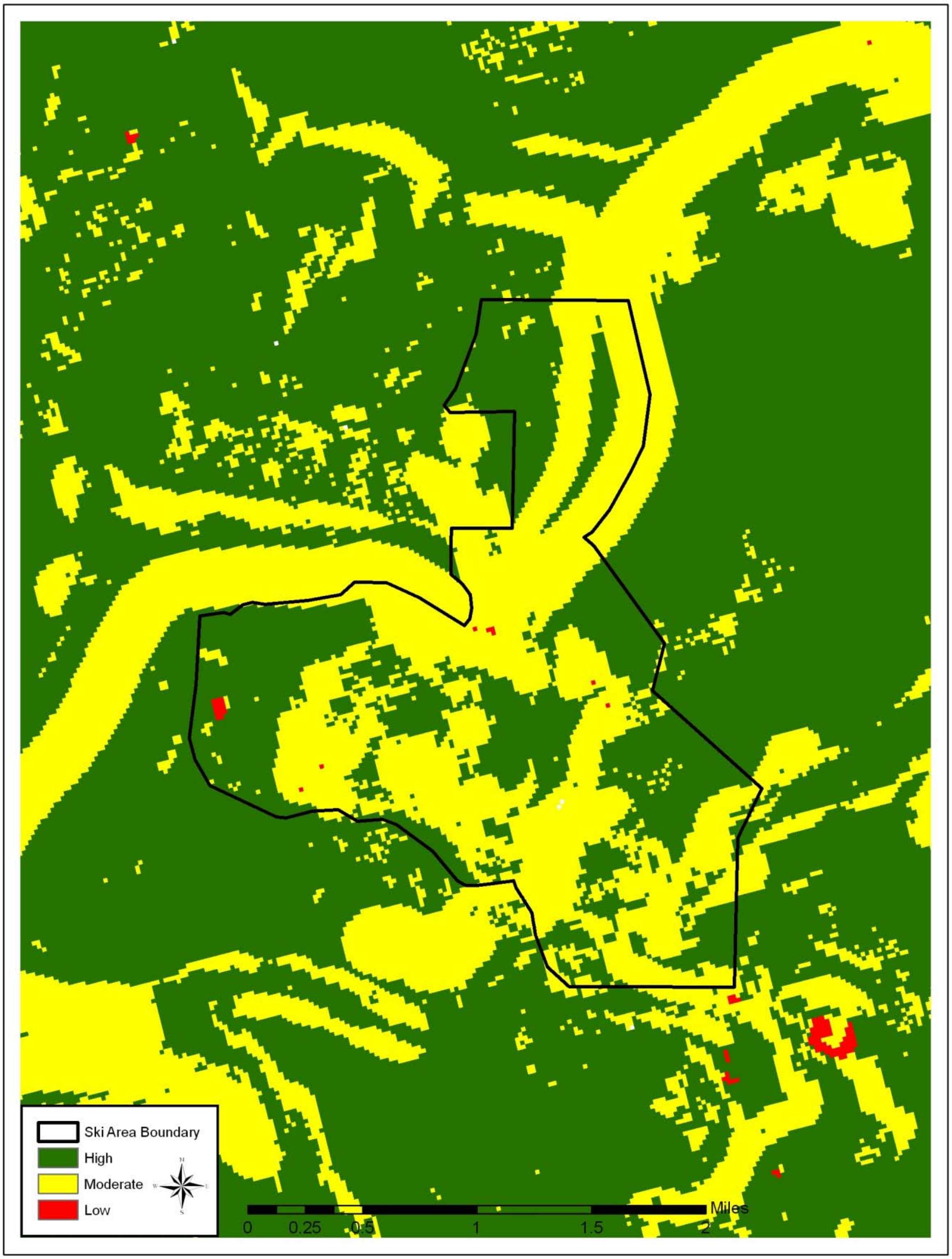

Figure 10. Canada lynx "existing condition" dispersal habitat suitability, grouped into "high," "moderate," and "low," for Stevens Pass Ski Area vicinity.

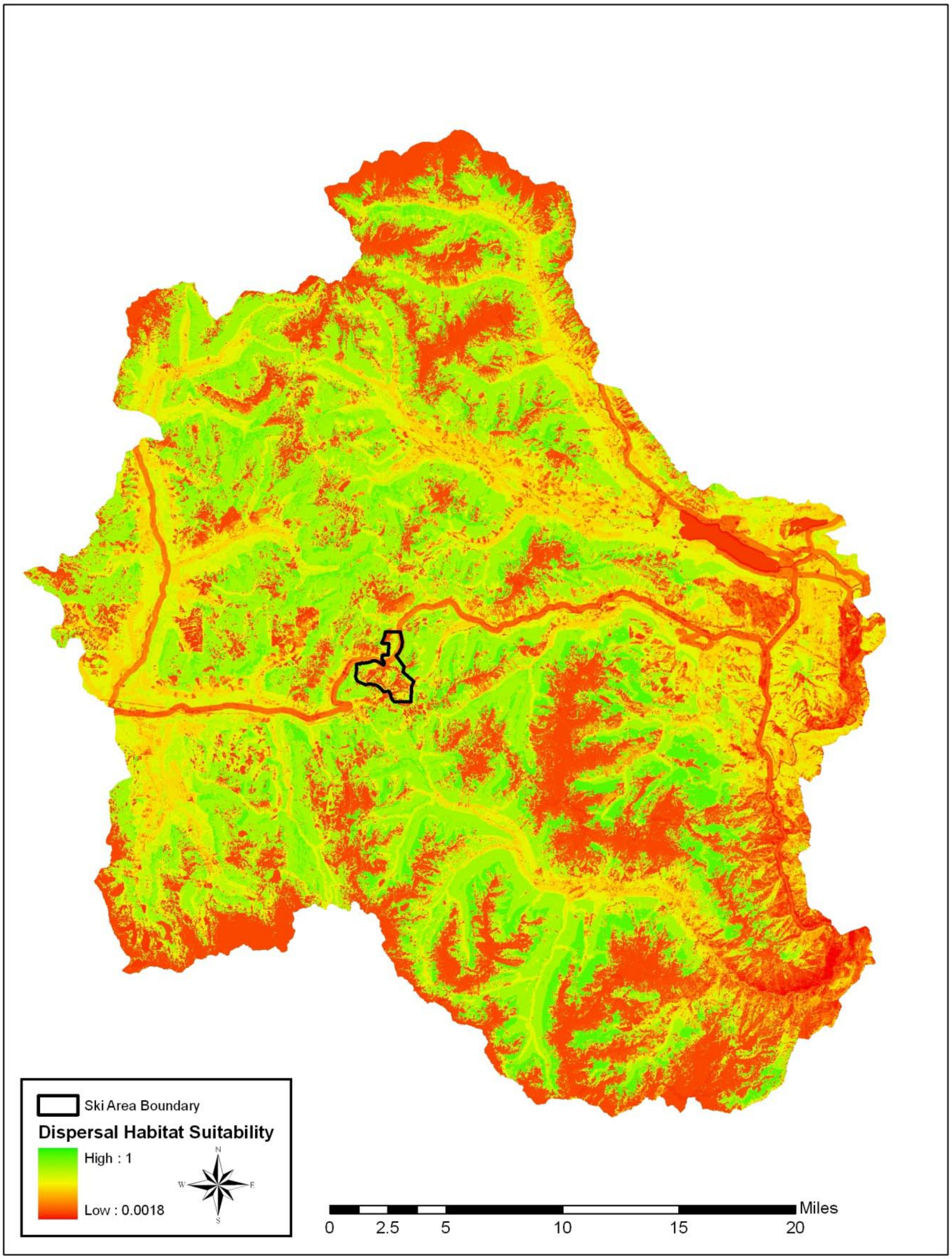

Figure 11. American marten “existing condition” dispersal habitat suitability for modeling extent.

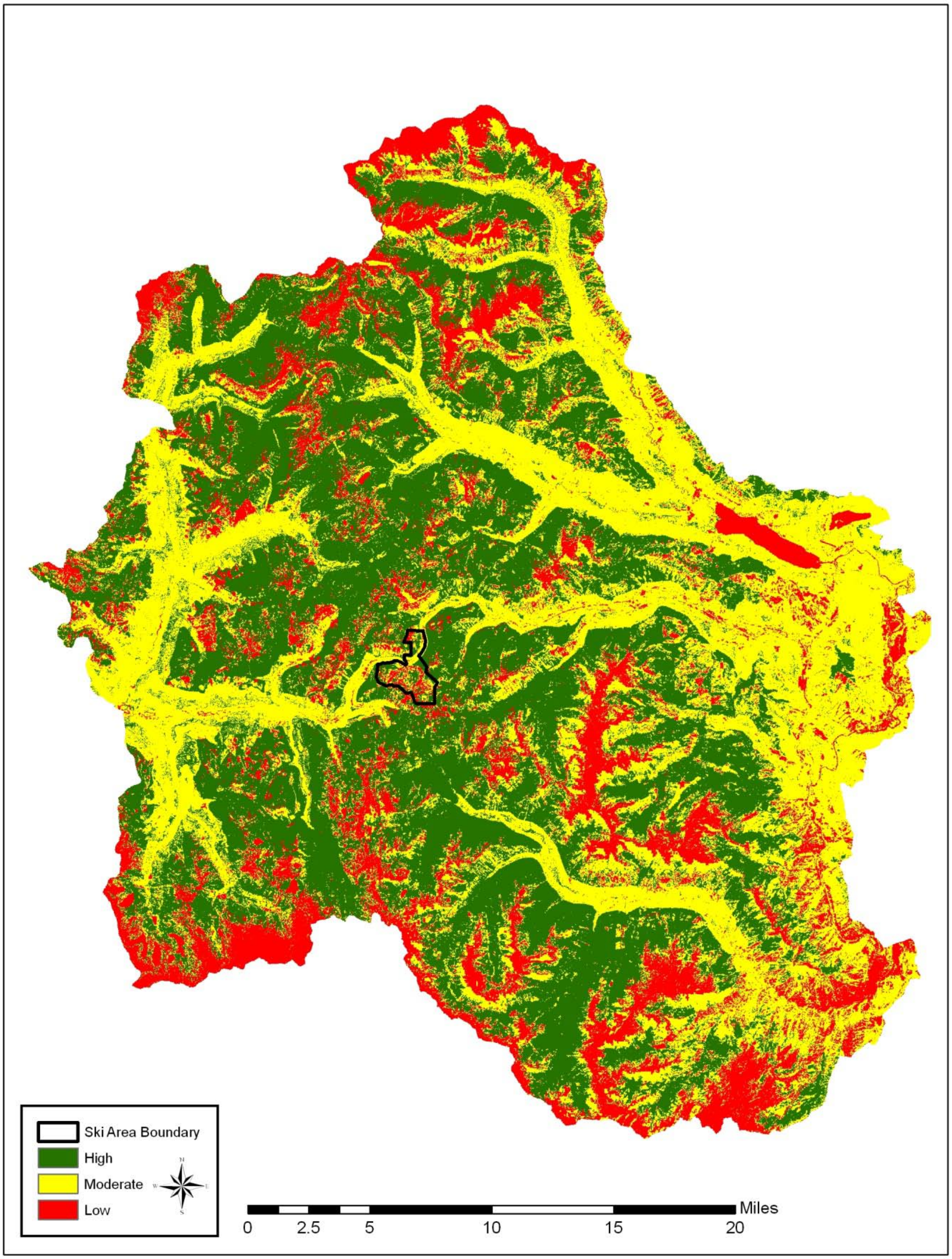

Figure 12. American marten “existing condition” dispersal habitat suitability for modeling extent with categorical grouping.

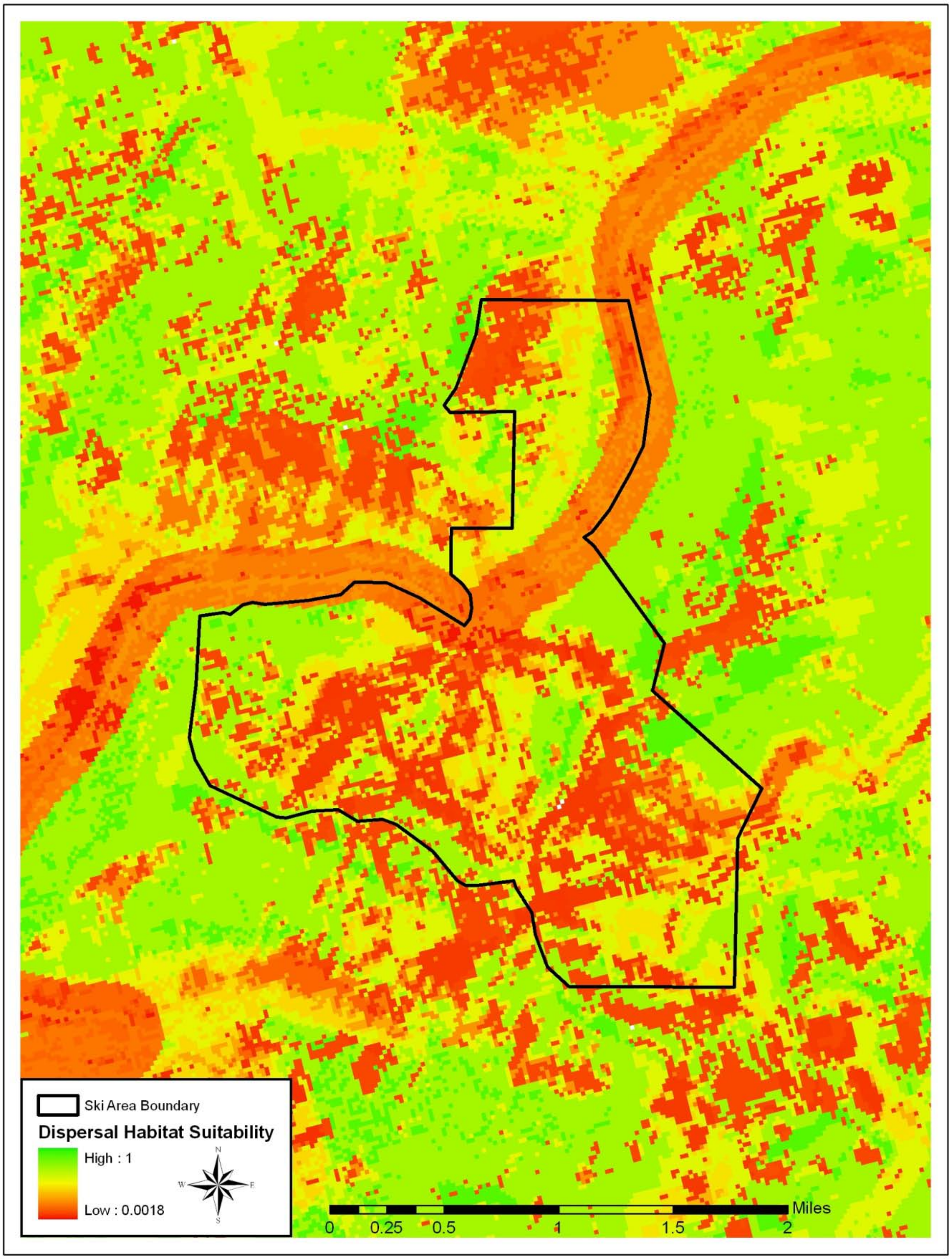

Figure 13. American marten "existing condition" dispersal habitat suitability for Stevens Pass Ski Area vicinity.

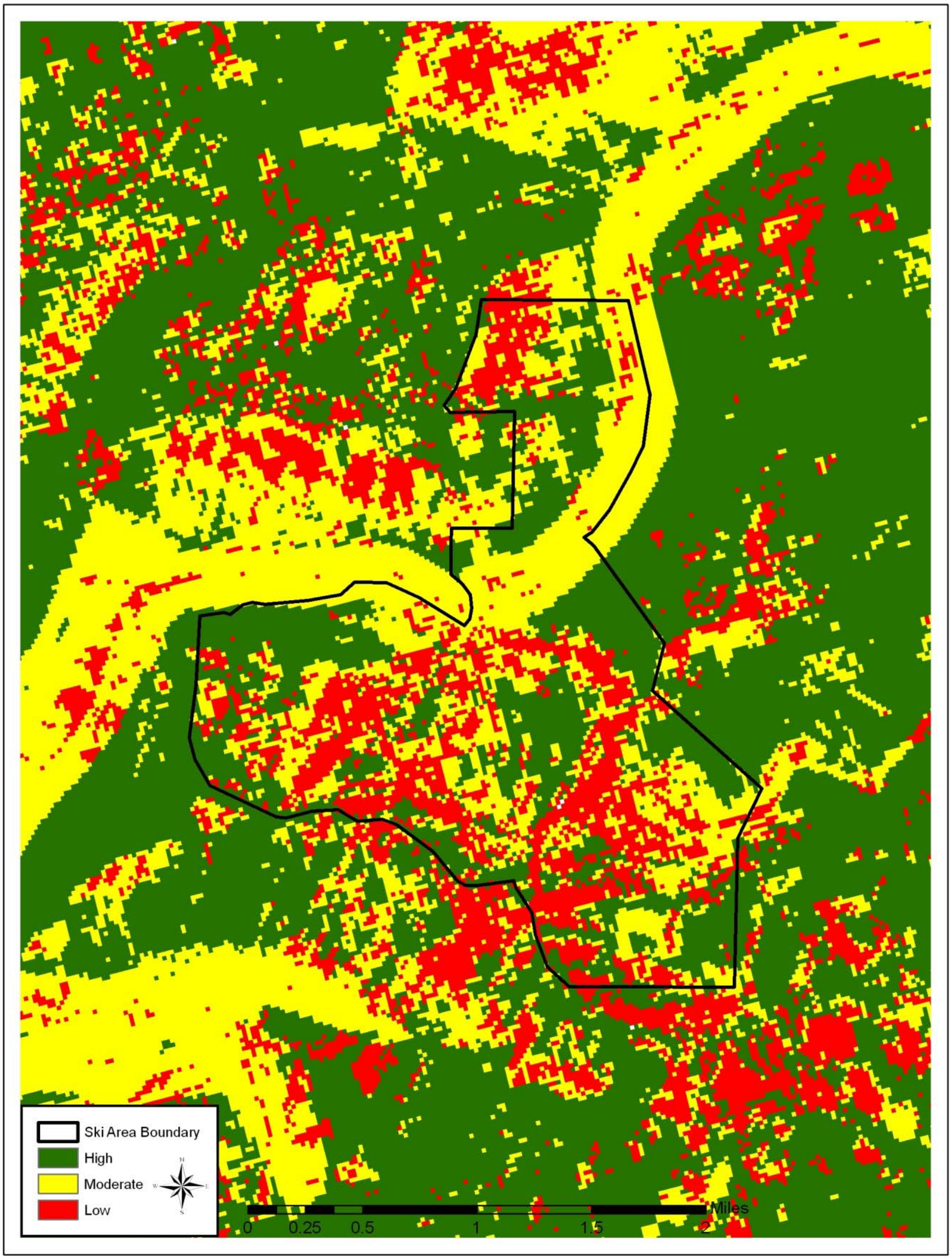

Figure 14. American marten “existing condition” dispersal habitat suitability, grouped into “high,” “moderate,” and “low,” for Stevens Pass Ski Area vicinity.

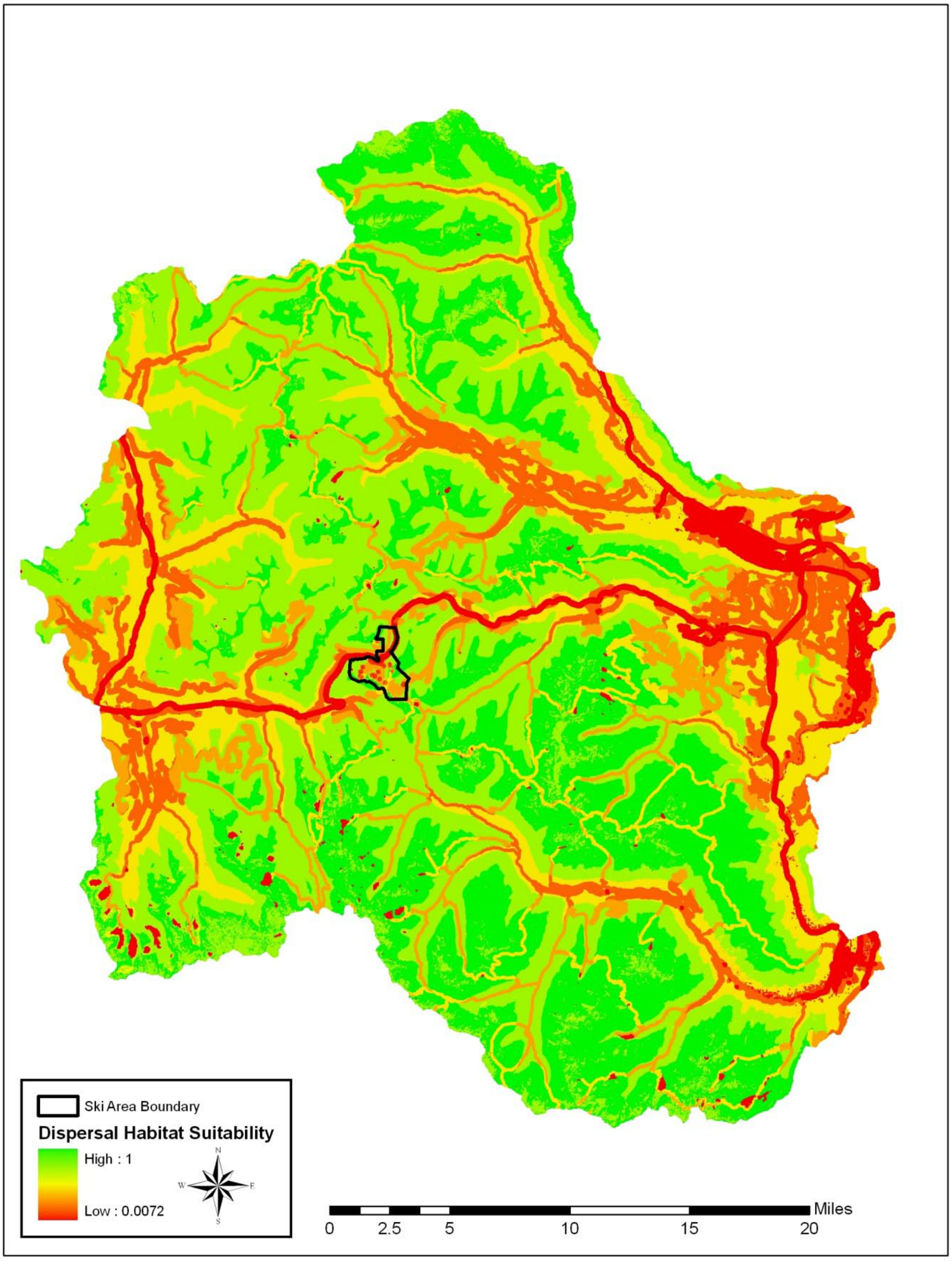

Figure 15. Wolverine "existing condition" dispersal habitat suitability for modeling extent.

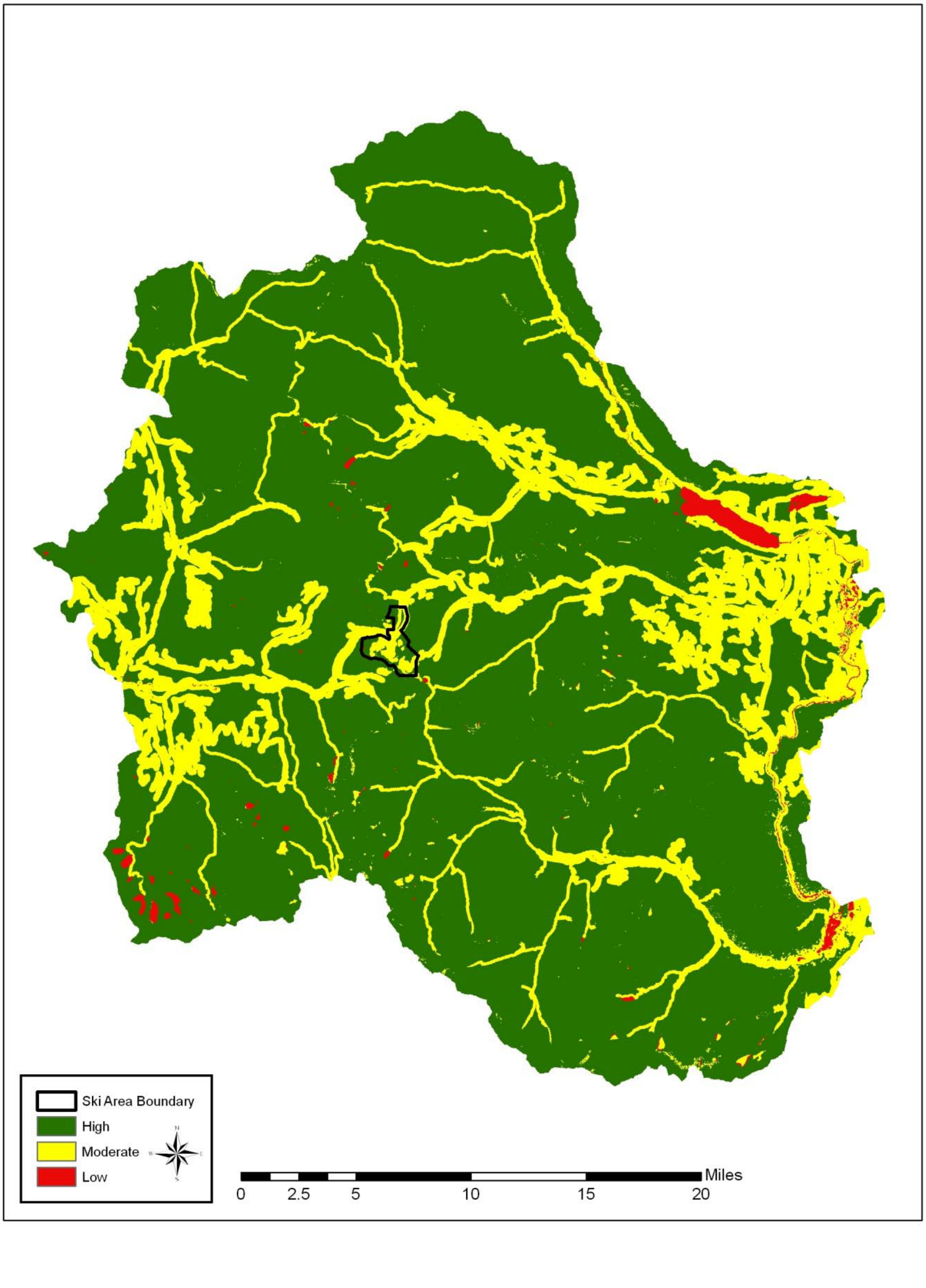

Figure 16. Wolverine “existing condition” dispersal habitat suitability for modeling extent with categorical grouping.

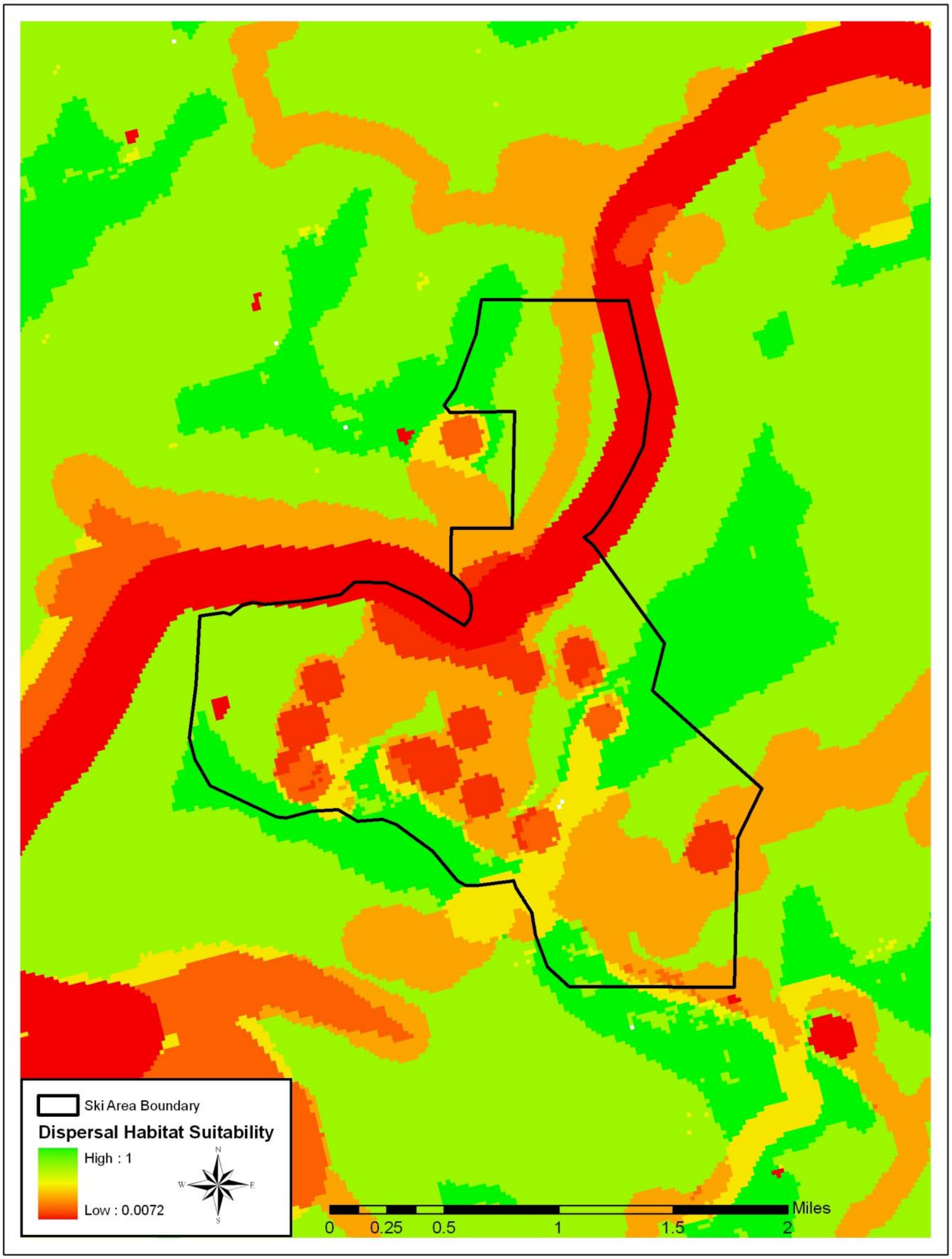

Figure 17. Wolverine "existing condition" dispersal habitat suitability for Stevens Pass Ski Area vicinity.

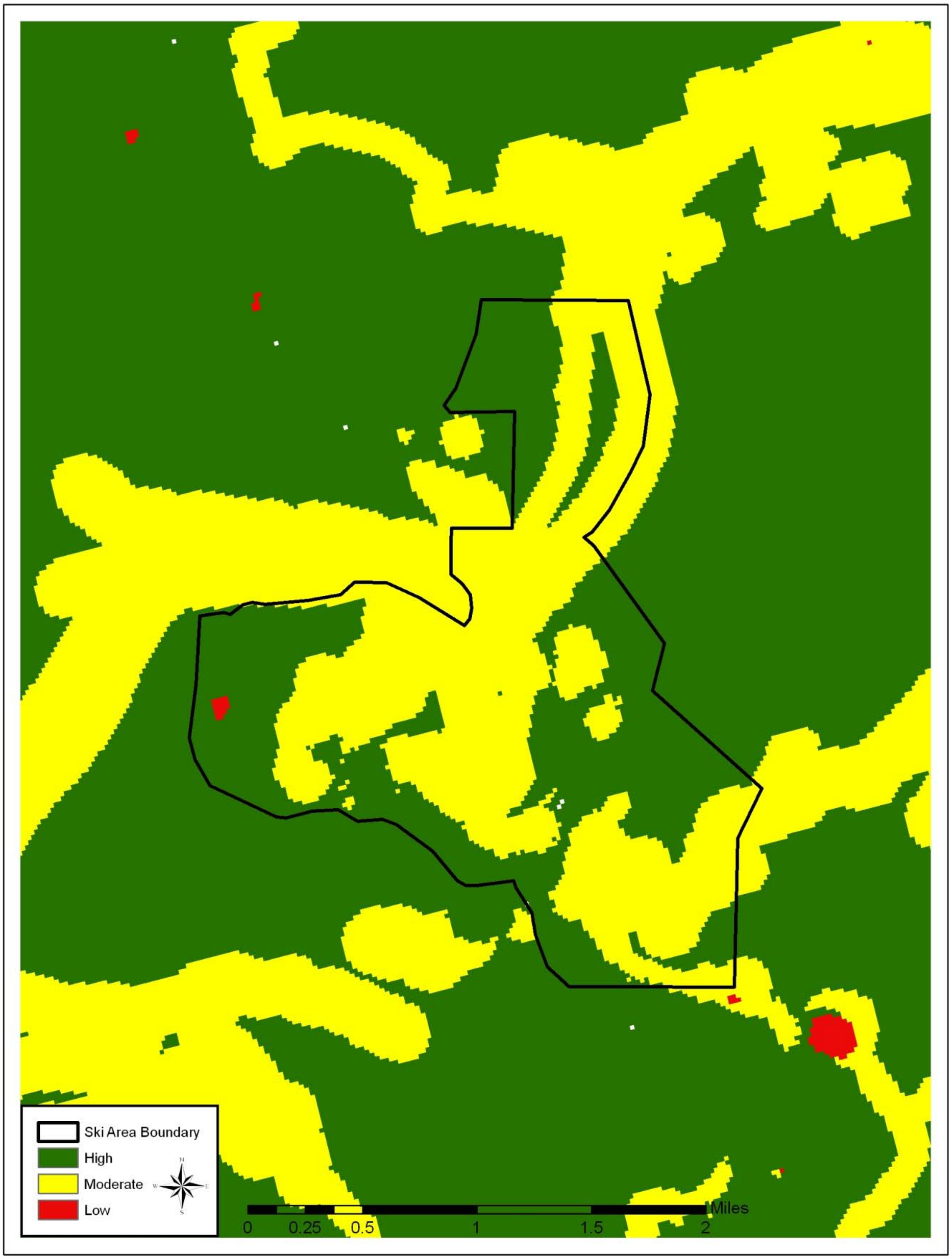

Figure 18. Wolverine "existing condition" dispersal habitat suitability, grouped into "high," "moderate," and "low," for Stevens Pass Ski Area vicinity.

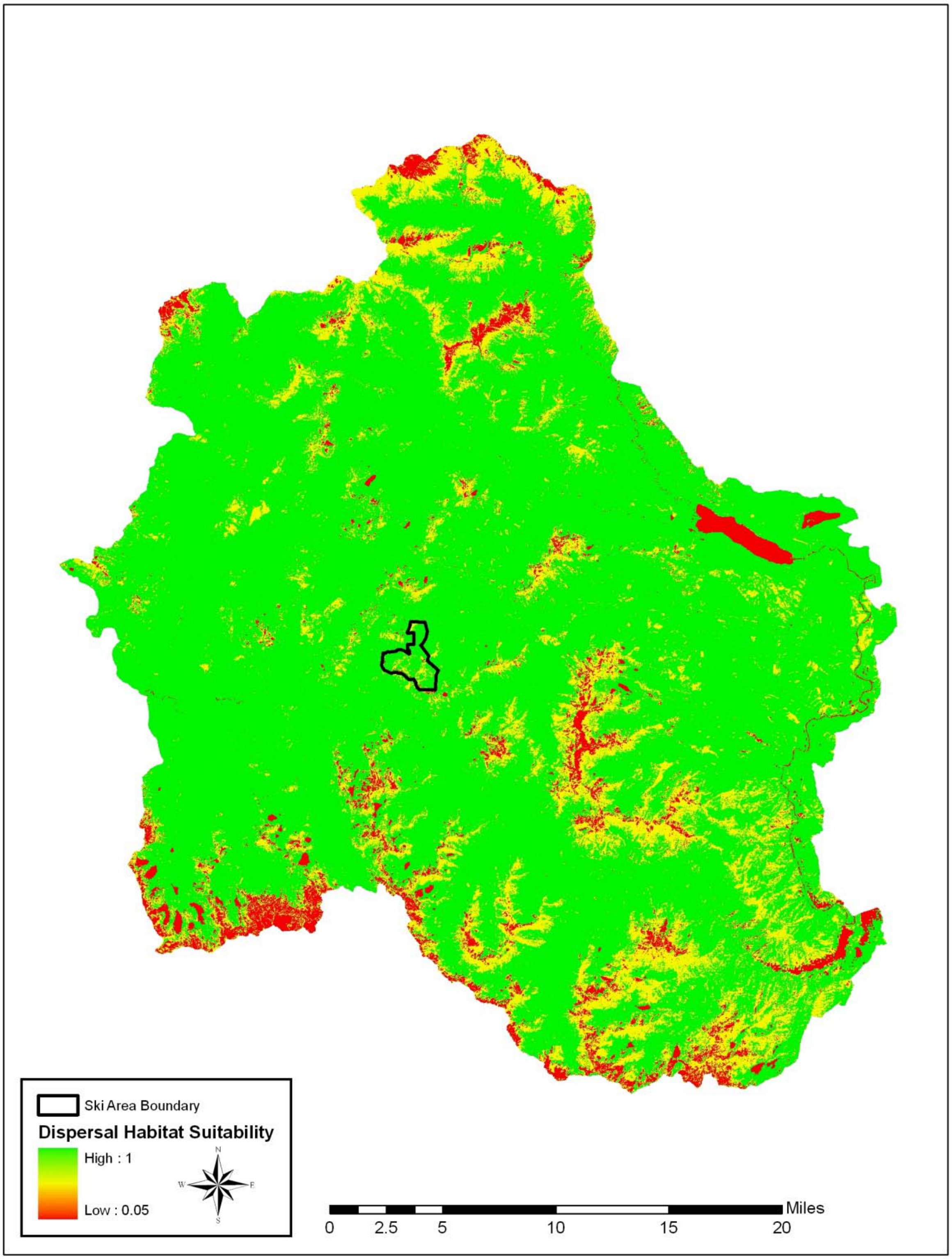

Figure 19. Grizzly bear “baseline” dispersal habitat suitability for modeling extent.

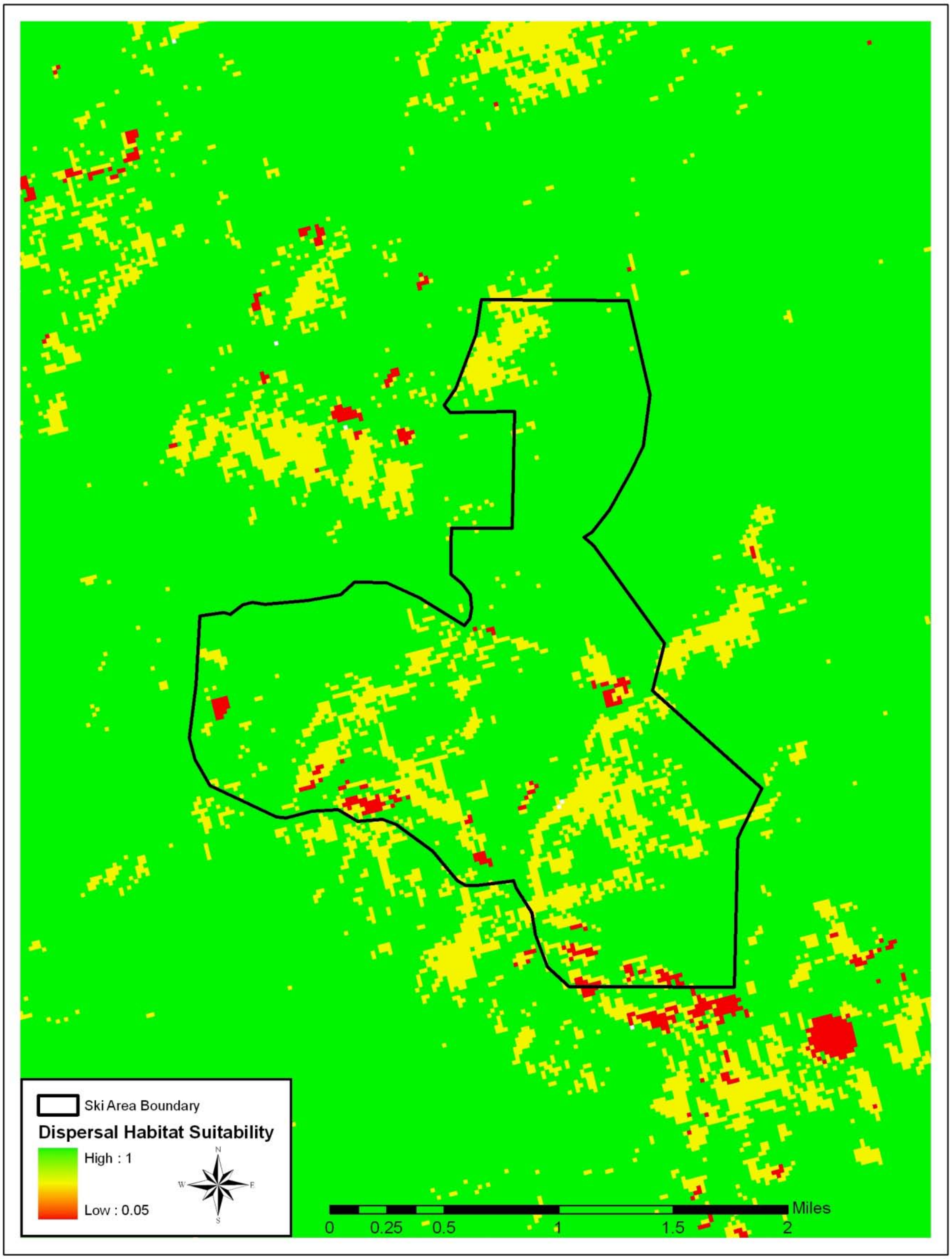

Figure 20. Grizzly bear “baseline” dispersal habitat suitability for Stevens Pass Ski Area vicinity.

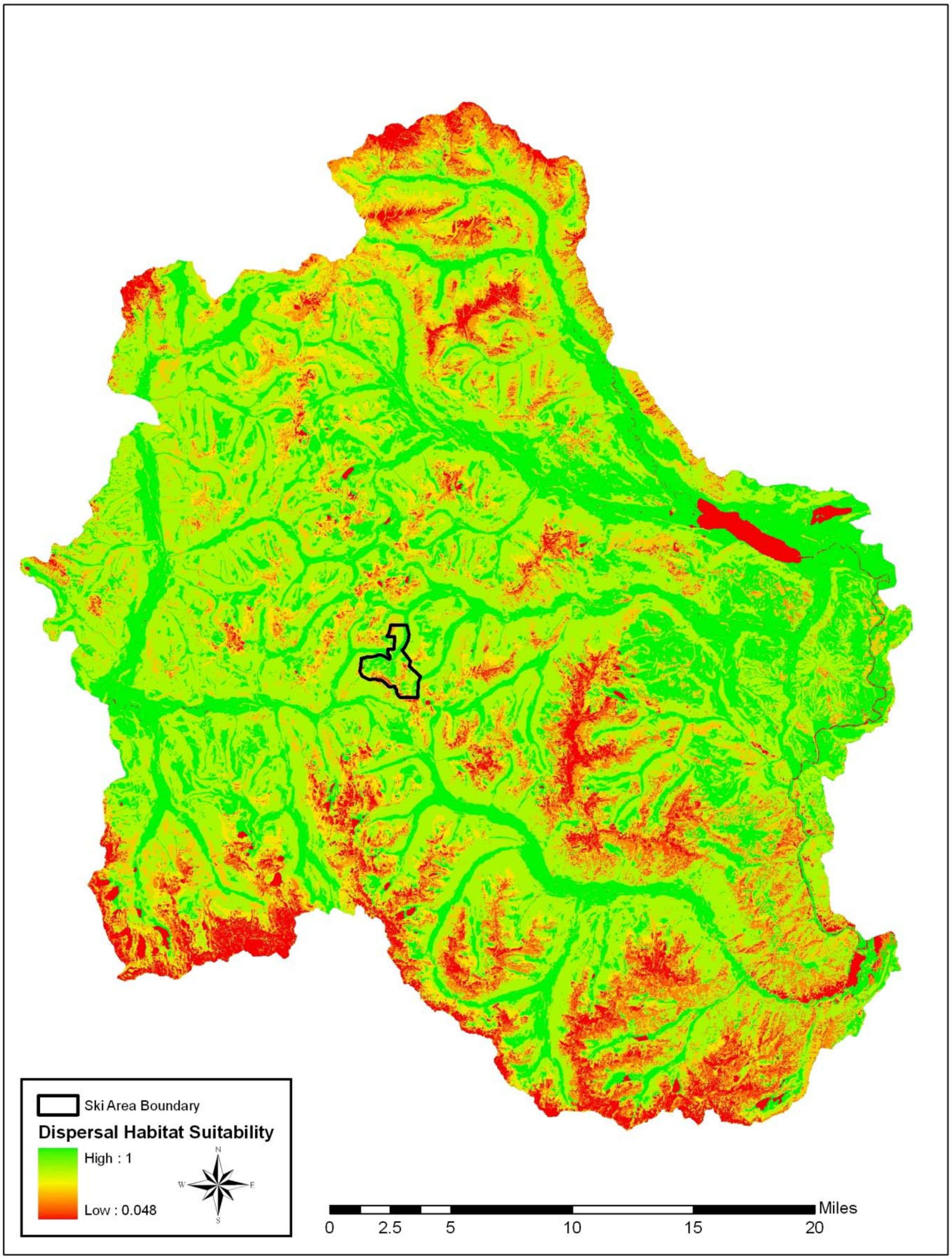

Figure 21. Canada lynx "baseline" dispersal habitat suitability for modeling extent.

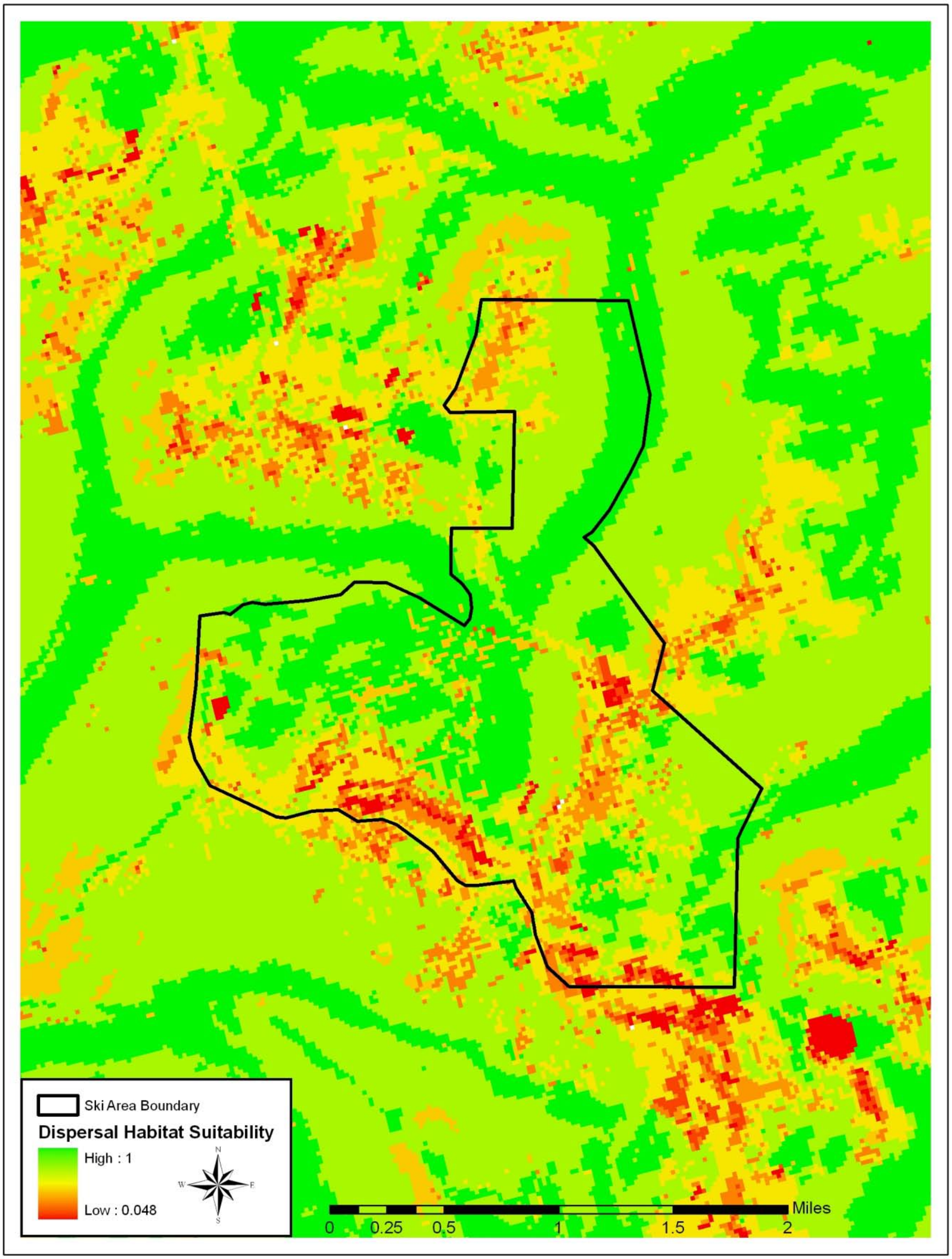

Figure 22. Canada lynx “baseline” dispersal habitat suitability for Stevens Pass Ski Area vicinity.

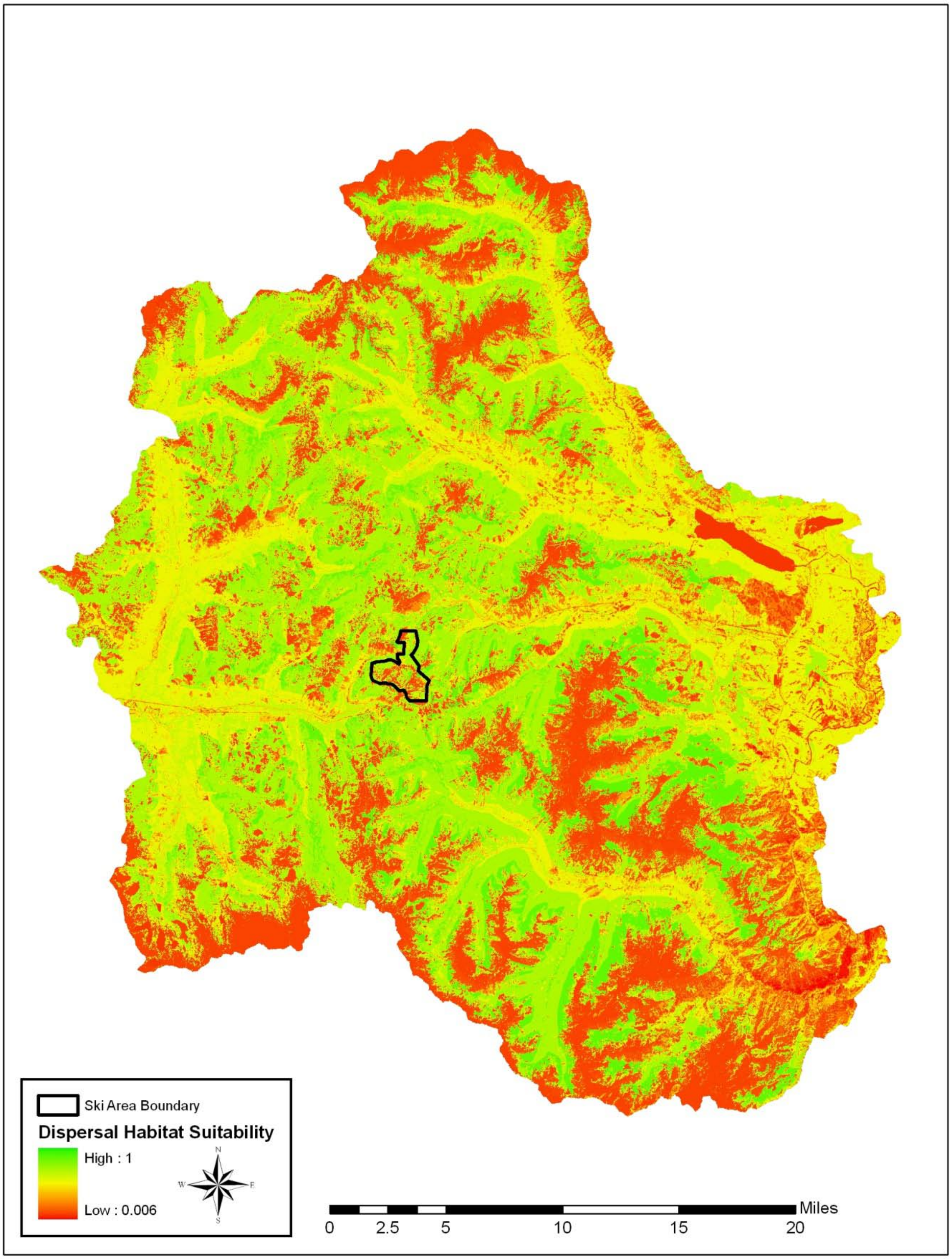

Figure 23. American marten "baseline" dispersal habitat suitability for modeling extent.

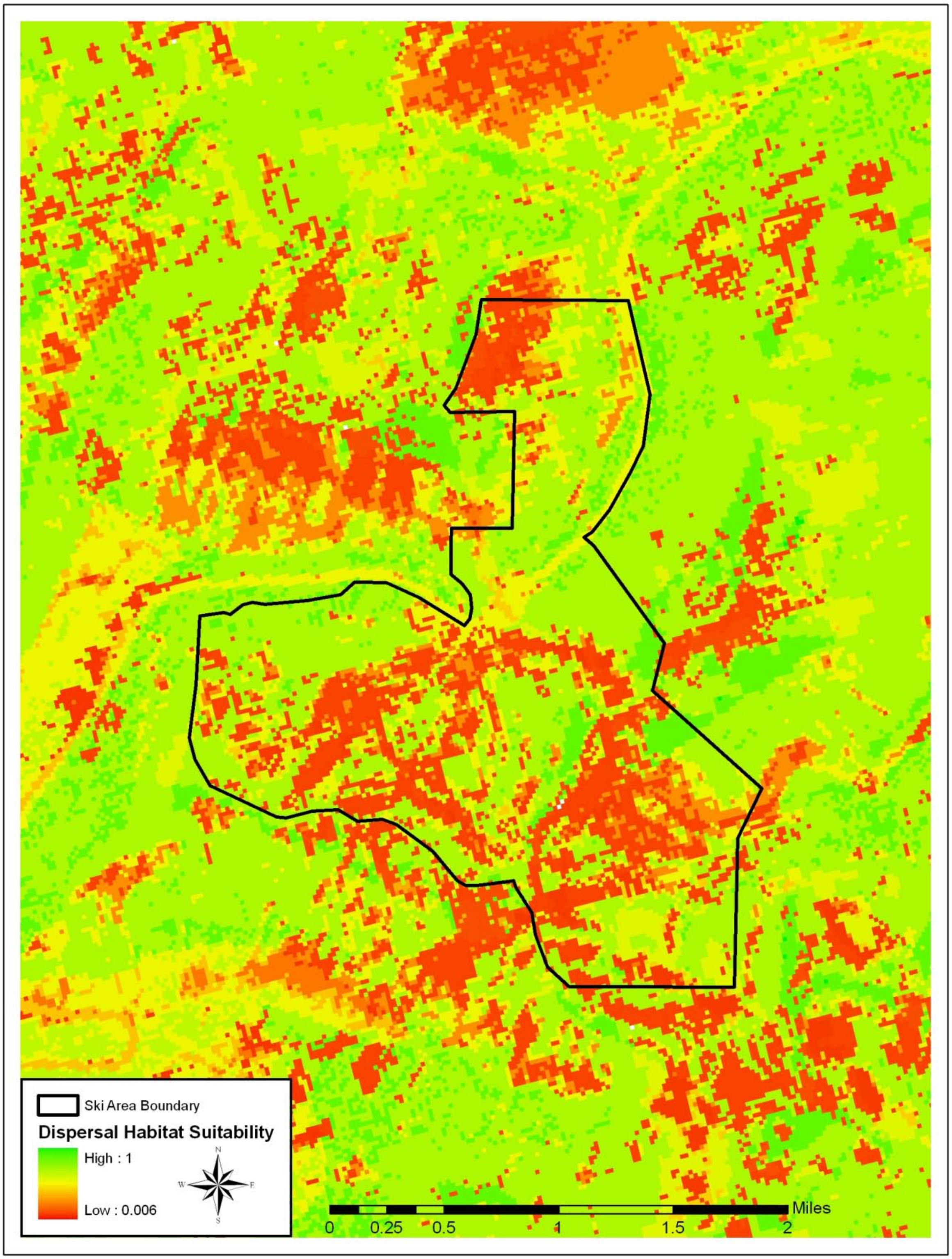

Figure 24. American marten “baseline” dispersal habitat suitability for Stevens Pass Ski Area vicinity.

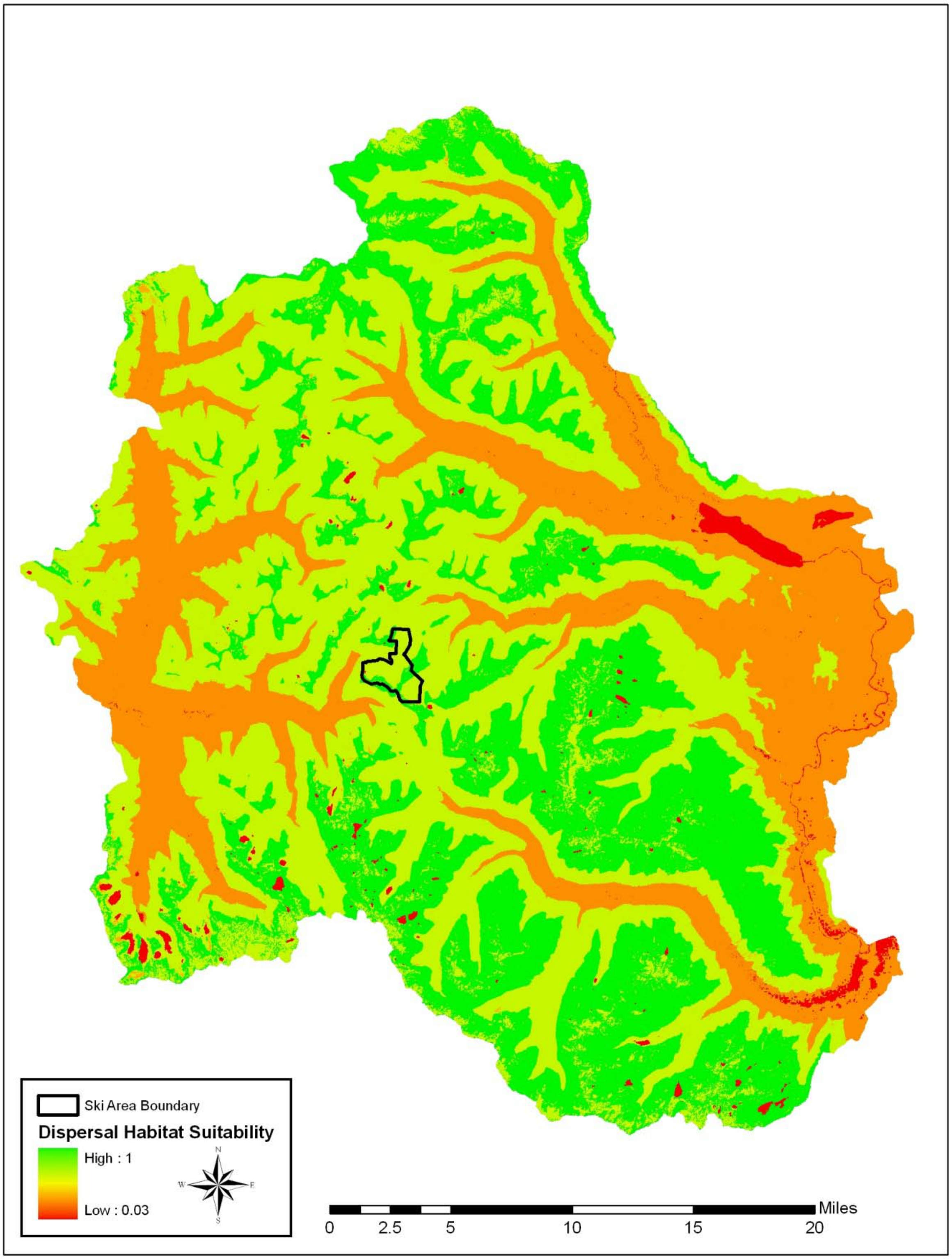

Figure 25. Wolverine "baseline" dispersal habitat suitability for modeling extent.

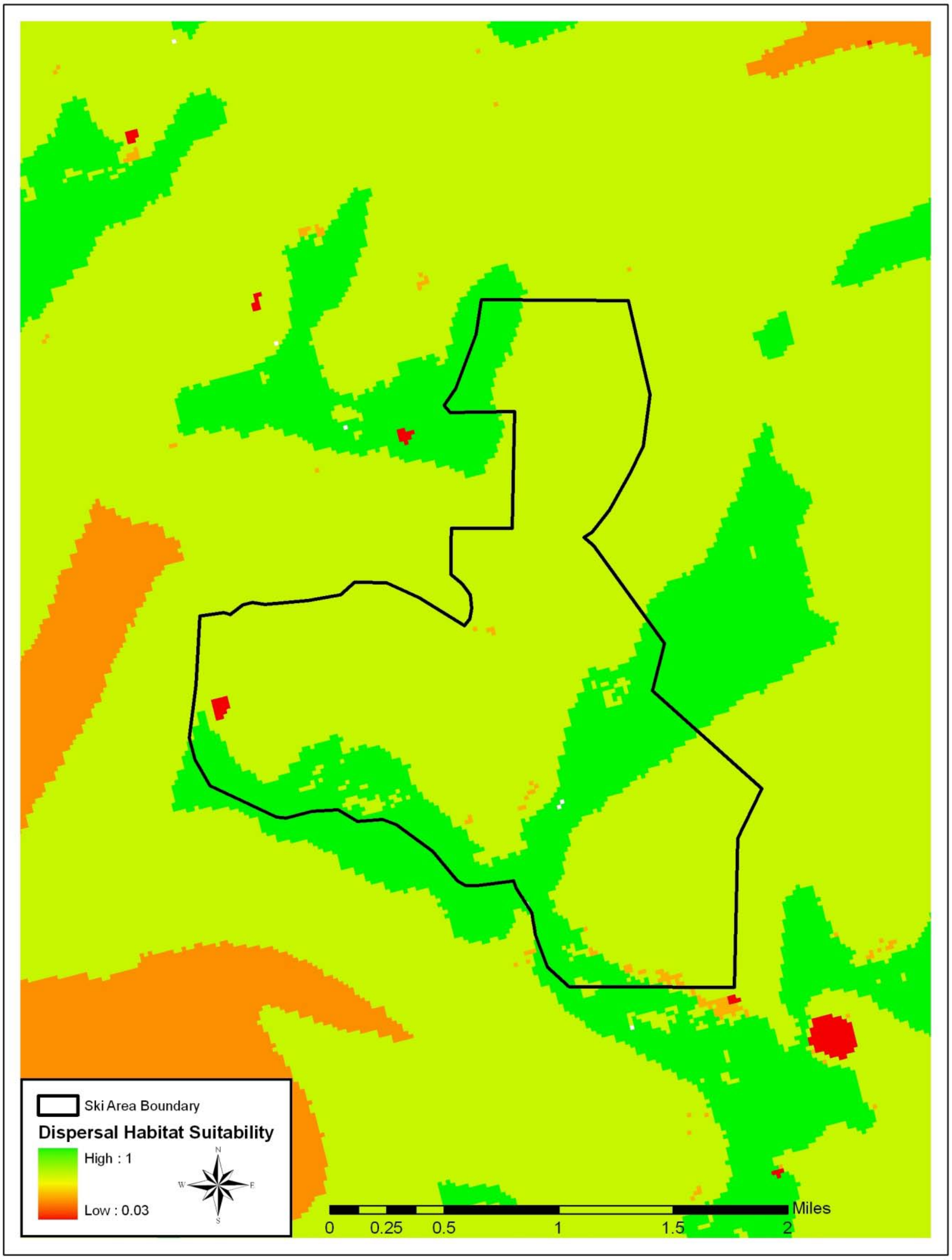

Figure 26. Wolverine "baseline" dispersal habitat suitability for Stevens Pass Ski Area vicinity.

Appendix A. Scientific Review Team for model method selection, GIS data selection, permeability value assignment, and output review.

Name	**Position**	**Affiliation**
Bill Gaines	Forest Wildlife Biologist	Okanogan-Wenatchee National Forest
Karl Halupka	Fish and Wildlife Biologist	United States Fish and Wildlife Service
Sonny Paz	Wildlife Biologist	Mt. Baker-Snoqualmie National Forest
Jesse Plumage	Forest Wildlife Biologist	Mt. Baker-Snoqualmie National Forest
Joe Scott	International Programs Director	Conservation Northwest
Peter Singleton	Ecologist	Wenatchee Forestry Sciences Lab
Brita Woeck	Wildlife Biologist	Tetra Tech Environmental Consultants
Don Youkey	Wildlife Biologist	Okanogan-Wenatchee National Forest