Spatial Framework for the Conservation of Canada Lynx Habitat in the Western U.S. and Associated Management Tiers

Interagency Western Lynx Biology Team

December 31, 2022

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1. PREFACE

This ***Spatial Framework for the Conservation of Canada Lynx Habitat in the Western U.S. and Associated Management Tiers,*** developed by the multi-agency Western Lynx Biology Team, is a revised approach to identifying high quality lynx habitat and managing vegetation for lynx conservation in the Western United States. Based on recent habitat distribution modeling efforts in the Northern Rockies, North Cascades (Olson et. al. 2021) and the Southern Rockies (Squires et. al. *in prep.*) that used fine scale GPS location data from a large sample of collared lynx covering much of the Western U.S., this Framework spatially identifies high quality lynx habitat to better focus conservation efforts. In addition, the Framework uses recent science to define desired vegetation structural characteristics that support lynx reproduction and occupancy.

Maps of lynx habitat created before this new refined mapping effort were developed in the absence of these data or modeling techniques and were broadly defined based on habitat types and elevation. The newly developed species distribution modeling indicates that areas of potential high-quality lynx habitat are more narrowly distributed than previously thought. Consequently, there is a large discrepancy between the amount of land currently mapped as lynx habitat across the Western U.S. and the new refined mapping approach. Variations exist regionally and locally.

Moreover, recent science provides a more precise understanding of the vegetation characteristics and structural mosaics associated with lynx home ranges than was available during the development of current management direction. Therefore, it is imperative that the revised depictions of high-quality lynx habitat be used in conjunction with the revised recommendations for vegetation management, to ensure that management efforts are focused on maintaining or enhancing habitat in areas of most value to lynx conservation.

This Framework recommends desired vegetation structural mosaics for Canada lynx conservation that are consistent with the best available science. The identified percentages of forests in the mature and advanced regeneration stages that best support lynx are based on recent data collected in the Rocky Mountains. It is possible that with fire suppression since European settlement the amount and distribution of mature forests in current western landscapes is higher than occurred under historical disturbance regimes. There is concern that maintaining 50-60% mature forest within Lynx Analysis Units[1] across the western landscape may not be sustainable given a warming climate and the increasing extent and intensity of wildfires and insect outbreaks. Occasionally, consideration of local conditions, climate regimes, and site potential may help to assess whether the desired vegetation structural characteristics

[1] A Lynx Analysis Unit is a landscape unit that approximates the size of a female lynx annual home range and encompass all seasonal habitats. LAUs are intended to facilitate analysis and monitoring of the effects of management actions on lynx habitat.

and mosaics can be achieved at a specific location. These areas are still capable of supporting lynx even though the desired vegetation structural mosaics may not be fully attainable. These areas should still be managed as lynx habitat up to its maximum potential.

The vegetation structural characteristics and mosaics in the Framework are recommended as a desired target. They reflect the conditions in known home ranges of resident lynx, including female lynx that produced litters, and are based on the most current empirical data available. However, it is important that this Framework be put in the context of a resilient landscape that embraces the habitat elements that support lynx productivity but considers uncertainty and climate change. As such, monitoring and adaptive management will remain central to the success of lynx conservation in the future.

Although this Framework refines the spatial extent of high-quality lynx habitat and the desired vegetation structural mosaics within those areas in the Western U.S., it is not a comprehensive lynx conservation strategy. Such a strategy would incorporate other factors that affect lynx habitat and selection, including the two main stressors influencing lynx habitat now: wildland fire and a warming climate. The development of forward-looking climate change scenarios and wildfire risk reduction strategies will be critically important to sustaining lynx habitat and populations into the future. We acknowledge that the Framework's revised habitat mapping is based on past data of lynx distribution and habitat use. It is important to understand and accommodate how the habitat defined in this Framework may move, shift, or become reduced as climate warming continues. Just as critical, to successfully sustain high-quality lynx habitat into the future, a landscape level, comprehensive wildfire risk/fuel reduction strategy is needed that could re-pattern the landscape to increase forest resiliency by reducing the likelihood of extensive wildfire spread to mature forest areas of lynx habitat. A complete lynx conservation strategy would also address other potential impacts, such as habitat fragmentation, human disturbances, and recreation for which there are new scientific findings. This Framework of refined lynx habitat mapping and vegetation management objectives should be used in conjunction with other lynx conservation and recovery efforts.

Existing lynx habitat management direction and procedures for Federal agencies will continue to apply until that direction is modified as needed to better align with the new science reflected in the refined lynx habitat map and new conservation recommendations of this Framework. It is likely that changes and additions to the existing direction will be needed given the substantial nature of the new science and the Framework for mapping and managing lynx habitat.

Federal agencies are required under Section 7 of the Endangered Species Act (1973) to consult with the U.S. Fish and Wildlife Service (USFWS) if any action they authorize, fund, or carry out may affect a listed species. Federal agencies must work with the USFWS to determine if any listed, proposed, or candidate species may be present in the action area. Where lynx may be present, federal agencies must consider potential effects of their proposed actions to lynx and consult with the USFWS if the proposed action may affect lynx. The processes and criteria used to determine where lynx "may be present" differ from those the Western Lynx Biology Team used to spatially define high quality habitat areas important for lynx conservation. Canada lynx are known to occur rarely or intermittently outside areas that support resident populations and outside areas of suitable habitat, including many areas outside the lynx habitat areas mapped in this Framework. Therefore, there will continue to be areas where lynx may be present that are outside of the areas identified in this spatial framework that will still need consultation with the USFWS.

We acknowledge that there are areas of lynx habitat outside of areas delineated in this Framework. While these areas include habitat of lower potential and are not the focus of lynx conservation, they may provide habitat for lynx dispersal and temporary use. Management of these areas should provide a mosaic of forest structure that includes dense early-successional coniferous and mixed-coniferous-deciduous stands, along with a component of mature multi-story conifer stands. Flexibility in the amounts and arrangement of various successional stages is acceptable, provided that a mosaic can be sustained. Vegetation treatments should be designed with consideration of historical landscape patterns and disturbance processes.

This Framework was developed in consultation with lynx researchers at the USFS Rocky Mountain Research Station and was independently reviewed by five other lynx researchers in the Western U.S. unaffiliated with its development. The researchers agreed that the refined map of lynx habitat and recommendations for desired vegetation structural mosaics contained in this Framework provide a strong foundation and defensible approach to better focus conservation efforts for the Canada lynx in the Western U.S. To sustain high quality lynx habitat into the future, they also stressed the importance of developing proactive climate change scenarios and wildfire risk reduction strategies. The ***Spatial Framework for the Conservation of Canada Lynx Habitat in the Western U.S. and Associated Management Tiers*** is an important step in that process.

2. INTRODUCTION

U.S. Forest Service (USFS), USFWS, and Bureau of Land Management (BLM) managers convened the Western Lynx Biology Team (hereafter, WLBT or Team) in May 2019. The purpose was to evaluate recent scientific research on Canada lynx (*Lynx canadensis)* habitat use and population demography, and incorporate it as appropriate into focused recommendations for revised forest management for lynx conservation and recovery on Federal lands in the West. This is in keeping with commitments to evaluate new scientific information as it becomes available and adjust forest management accordingly by applying the best available science to efforts to conserve lynx and snowshoe hare (*Lepus americanus*) populations and habitats in the Lynx Conservation Assessment and Strategy (LCAS; Interagency Lynx Biology Team 2013), Northern Rockies Lynx Management Direction (NRLMD; U.S. Forest Service 2007), the Southern Rockies Lynx Amendment (SRLA; U.S. Forest Service 2008), and individual USFS forest plans and BLM land and resource management plans.

*NOTE: When using internal hyperlinks in this paper, return to your previous view by pressing **Alt + Left Arrow** on your keyboard.*

New information about lynx habitat use and distribution has become available in the more than 20 years since the contiguous U.S. population of Canada lynx was listed as threatened under the Endangered Species Act (ESA) in 2000. Early efforts to map lynx habitat over-estimated potential lynx habitat in the western U.S. These efforts relied on broad vegetation associations (spruce-fir-lodgepole pine communities), elevation considerations, and verified and anecdotal records of both resident and dispersing lynx (Ruediger et al. 2000, U.S. Fish and Wildlife Service 2005, Interagency Lynx Biology Team 2013). Research over the last 20 years indicates that lynx habitat capable of supporting persistent use is more narrowly distributed than previously thought. Existing maps of lynx habitat do not distinguish areas of varying habitat quality in areas that may support lynx occupancy, and include areas that the new science suggests have little or no capability to support lynx. For the most effective lynx conservation across the western landscape, it is important to focus management effort and limited resources in areas of highest habitat capability. Thus, Federal forest management plans may need to be revised or amended to incorporate the best science.

The WLBT, with advice from lynx researchers, developed a more focused framework for the conservation and recovery of lynx on Federal lands which refines and standardizes lynx habitat maps across agencies, given our diverse missions and land bases.

The spatial framework for lynx habitat conservation consists of two parts:

1. Using the new species distribution models created by Olson et al. (2021) and Squires et al. (*in prep.*), areas where conservation for lynx should be focused in the western U.S. were identified and delineated. The models are based on the best empirical data of lynx locations across the western U.S. landscape. The models accurately map abiotic and biotic features that lynx consistently selected at known locations of breeding and non-breeding individuals within and outside of home ranges in Montana, Washington, Wyoming, and Colorado.

2. Within this refined spatial depiction of lynx habitat, management tiers were developed based on recently published scientific research, clarifying habitat conditions associated with home ranges and core use areas which support lynx residency and reproduction. This framework accounts for habitat connectivity as well.

3. OVERVIEW

3.1 A Brief History of the Lynx Biology Team

In response to a 1998 proposal by the USFWS to list Canada lynx in the contiguous (i.e., "Lower 48") United States as a threatened Distinct Population Segment (DPS) under the ESA, Ruggiero et al. (2000) developed a "science team" that wrote a synthesis of best available science on lynx ecology titled "Ecology and Conservation of lynx in the United States" published by University Press of Colorado. With the ongoing assistance of the science team that developed that report, a national Lynx Biology Team of Federal biologists from the USFWS, USFS, BLM, and National Park Service was then chartered to synthesize information in the science report, identify potential risk factors, and recommend conservation measures range wide for lynx in the DPS. This effort by the Interagency Lynx Biology Team resulted in the LCAS (Ruediger et al. 2000). The LCAS was influential in guiding national conservation efforts for the Canada lynx, Federal land and habitat management for the species, and interagency ESA section 7 consultations. Conservation measures in the LCAS became legally binding commitments for the Forest Service as they formed the basis of regional forest plan amendments for National Forests in the northern (NRLMD, U.S. Forest Service 2007) and southern (SRLA, U.S. Forest Service 2008) Rockies. Other regions of the Forest Service and other agencies continued to rely primarily on the LCAS itself and continue to do so today. The LCAS was fully revised more recently (Interagency Lynx Biology Team 2013) and continues to be the primary guidance for land management agencies in other regions across the range of the Canada lynx in the U.S. The Lynx Biology Team continued to provide periodic support, clarification, and guidance in implementation of the LCAS and regional forest plan amendments for several years, until largely dissolving having fulfilled its primary role.

3.2 Re-emergence of a Western Contingent of the Lynx Biology Team

The Western Lynx Biology Team, convened in May of 2019, is enacted by an interagency and inter-regional Steering Team of Federal, regional and state directors within the USFS, USFWS, and BLM within the geographic scope of the western range of the Canada lynx.

During the three years of development for this framework, Team members have included:

- Scott Jackson - USFS, National Carnivore Program Leader, Team Leader
- Megan Kosterman - USFWS, Idaho Field Office (FO)/Minnesota-Wisconsin FO
- Jim Sparks - BLM, Montana
- Rema Sadak - USFS, Intermountain Region (R4)
- Jim Zelenak - USFWS, Montana FO
- Anne Orlando - BLM, Montana
- Gary Hanvey - USFS, Northern Region (R1)
- Gregg Kurz - USFWS, Central Washington FO
- John Rohrer - USFS, Okanogan-Wenatchee National Forest (R6)
- Aimee Crittendon - USFWS, Western Colorado FO
- Peter McDonald - USFS, Rocky Mountain Region (R2)
- Carly Lewis – USFWS, Region 6
- Chris Boone – BLM, Montana

Science consultants to the WLBT are:

- John Squires – Science Advisor to the Western Lynx Biology Team (17 June 2019). USFS, Rocky Mountain Research Station, Research Wildlife Biologist

- Lucretia Olson - USFS, Rocky Mountain Research Station, Ecologist

Additional support to our team has included:

- Karen Dunlap - USFS, Northern Region (R1), Ecosystem Assessment & Planning, Logistical Support
- Cara Staab – USFS Steering Team Liaison
- GIS Support
  - Kelsey David, Peter Davis, Mary Bergkamp-Hattis - USFS, Northern Region (R1)
  - Victoria Smith-Campbell, Taylor Willow - USFS, Rocky Mountain Region (R2)

3.3 Climate Change Considerations

As early as 2005, the U.S. Fish and Wildlife Service (Service) concluded that ongoing and projected climate warming was likely to negatively affect the cold climatic conditions that maintain the boreal and montane ecosystems to which lynx are highly adapted (U.S. Fish and Wildlife Service 2005, p. 11). The Service anticipated that continued warming could cause a northward and upslope contraction of these systems to the detriment of lynx populations (*Ibid.*), potentially resulting, eventually, in a substantial decrease or possible elimination of lynx habitats from in the contiguous United States (*Ibid*, p. 14).

In 2013, the Interagency Lynx Biology Team (ILBT) included climate change in its First Tier of anthropogenic influences - those with the potential to have population-level consequences - likely to impact lynx habitat in the contiguous United States (Interagency Lynx Biology Team 2013, pp. 68-71). The ILBT recognized several likely or possible effects of climate change on lynx and snowshoe hares, including northward and upslope shifts in distribution, changes in the dynamics of snowshoe hare and lynx population cycles, reduced habitats and population sizes, changes in other demographic rates, and changes in predator-prey relationships (*Ibid*, pp. 43, 53, 55, 62-63, 66, 68-71). The ILBT also recognized climate-driven changes in natural disturbance regimes, especially the increasing size, frequency, and intensity of wildland fires and forest insect outbreaks related to warming and drying climate conditions were likely to negatively impact lynx but that there remained much uncertainty about the mechanisms, magnitude, and timing of such impacts (*Ibid*, pp. 66, 76, 98).

Likewise, in 2015, the Service sought expert input on the “timing, extent, magnitude, and severity of potential threats associated with climate change” on the current and future viability of lynx and hare populations and habitats in the contiguous United States (Canada Lynx Species Status Assessment Team [Lynx SSA Team] 2016, pp. 6, 10, 14-17, 19, 21-23, 36-48). Experts considered the direct and indirect effects of climate change to pose the greatest challenge to future long-term viability of lynx populations in the contiguous United States. Anticipated effects included potential “climate-driven increases in the size, frequency, and intensity of fire and insect outbreaks; decreases in snow amount, duration and quality, leading perhaps to increased competition with bobcats and other hare predators; and the projected warming-induced northward and upslope migration of boreal and subalpine forests that would result in the loss and further fragmentation and isolation of lynx and hare habitats" (*Ibid*, p. 58). Again, however, experts expressed great uncertainty about the timing, extent, and magnitude of these potential impacts and recognized that they would likely vary depending on future greenhouse gas emissions scenarios (*Ibid*.).

In the Canada lynx species status assessment (SSA), the Service recognized that the lynx, as a boreal forest- and snow-associated specialist predator, is probably broadly exposed and highly sensitive to the projected impacts of continued climate warming and has limited capacity to adapt to it. Therefore, the Service considers lynx populations in the DPS to be vulnerable (predisposed to be adversely affected) to the projected impacts climate change (U.S. Fish and Wildlife Service 2017, p. 20). Thus, the Service concluded that continued climate warming and associated impacts, particularly increased wildfire and forest insect activity, were likely to reduce the amount and quality of lynx habitats, lynx numbers, and the resiliency of lynx populations in the contiguous United States (*Ibid*, pp. 4-8). The Service expects all lower-48 lynx populations to become smaller and more patchily distributed in the future due largely to climate-driven losses in habitat quality and quantity but recognizes that the timing, rate, and extent of climate-mediated impacts remains highly uncertain (*Ibid*, pp. 10, 67-83).

Climate-driven changes in natural disturbance regimes such as increased size, frequency and intensity of wildland fires and forest insect outbreaks are expected to continue and perhaps accelerate in lynx range (Lynx SSA Team 2016, p. 58), likely making lynx populations vulnerable (predisposed to be adversely affected) to the impacts of climate change (U.S. Fish and Wildlife Service 2017, p. 20). For example, large wildfires in north-central Washington have reduced lynx habitat by 35-40 percent (1401 km^2 [541 mi^2]) between 1994-2016 (*Ibid*, pp. 78, 149) and the Diamond Creek fire of 2017 burned an additional 393 km^2 (152 mi^2) of lynx habitat in this unit, along with another 126 km^2 (49 mi^2) across the border in southern British Colombia (*Ibid*, p. 149). In the northwest Montana/northeastern Idaho geographic unit, approximately 15 percent (4,172 km^2 [1,611 mi^2]) of the forest area encompassing lynx habitat burned between 2000-2013 (Squires *in* Lynx SSA Team 2016, p. 20) and an additional 1,150 km^2 (444 mi^2; over 4 percent of the unit) burned during the 2017 fire season alone, including the Rice Ridge/Reef and Liberty fires, which together burned 764 km^2 (295 mi^2) in the core of the Seeley Lake population's habitat. Since 2000, spruce beetle outbreaks have caused tree mortality on roughly 1.87 million acres (7,568 km^2 [2,922 mi^2]) in Colorado, and about 41 percent of the spruce-fir forests in the state have now been affected (Colorado State Forest Service, accessed November 2022).

Within the context of this conservation framework, impacts to lynx habitat from climate-driven changes to historical disturbance regimes will need to be carefully evaluated and adaptive management strategies applied that are focused on the conservation of the species. For example, there may be a need to develop future management actions that expedite the restoration of lynx habitat and maintain and/or enhance the remaining lynx habitat in these affected areas.

Although this framework does not specifically outline conservation recommendations in the context of climate change, we recognize and highlight the need to use adaptive management strategies in areas where the amount and configuration of lynx habitat have been adversely impacted by climate-mediated changes to historical disturbance regimes.

4. EXISTING LYNX HABITAT MAPS

Some federal agencies initially mapped lynx habitat in the late 1990s when lynx were considered a “sensitive” species; and most had completed initial mapping by 1999 for use in conducting the National Lynx Survey using initial habitat definitions developed by the Lynx Biology Team. Currently, existing habitat maps used in Federal planning and decision-making are based on mapping direction and habitat definitions developed by the Lynx Biology Team, as described in Ruediger et al. (2000). Although most federal agencies refined their initial maps to incorporate direction provided in Ruediger et al. (2000), some mapping inaccuracies occurred due to: 1) an incomplete understanding of snow variables (annual snowfall amount, duration of the snow season, and snow conditions – e.g., “deep/fluffy”) associated with lynx occurrence or residency, and either did not apply an elevational gradient or threshold, or elevational thresholds were too low; 2) over-mapping of secondary vegetation (mesic Douglas fir, grand fir, western larch, and aspen habitat types) that was not immediately adjacent to or intermixed with primary vegetation (subalpine fir / Engelmann spruce habitat types); and/or 3) databases that were insufficient to accurately map habitat types. Since 2000, some agencies and many National Forests have updated their maps in an attempt to correct inaccuracies and/or improve them based on refined vegetation data layers so that they better align with the habitat definitions provided in Ruediger et al. (2000). However, some National Forest maps have not been updated, and lynx habitat on those Forests is likely over-mapped.

We note importantly that existing lynx habitat maps do not distinguish between habitats capable of supporting persistent resident lynx populations from those that may serve other ecological functions (e.g., habitats that may support lynx residency but not reproduction; others that may support dispersal/connectivity but not residency), nor was there a defensible framework to accurately map habitat that was suitable but unoccupied. Thus, existing lynx habitat maps tend to overestimate habitat capable of supporting lynx. Additionally, some National Forests have also over-mapped lynx habitat. A primary focus of new lynx research has been to identify the quality habitat that lynx consistently use based on available lynx telemetry location data, and a combination of biotic and abiotic factors to predict habitat capability across larger landscapes. The development of maps based on modeled habitat capability (i.e., potential habitat suitability) allows agencies to focus on those areas most likely to have the highest habitat and conservation value to Canada lynx in the western U.S, and provides a defensible approach to map habitat across areas that are currently unoccupied and without actual data on lynx presence.

5. NEW LYNX HABITAT MODELS

Olson et al. (2021) and Squires et al. (*in prep*.) more recently developed new species distribution models for the Canada lynx in the western part of the DPS range. The conservation aim of their studies was to model the distribution of habitat capable of supporting lynx across the western U.S., including areas outside known populations.

5.1 Habitat quality, capability, and suitability

Species distribution models (SDM) compare environmental conditions at presence and background locations to calculate a relative probability of habitat suitability (Elith and Leathwick 2009) and provide a means for understanding the distribution of a species' habitat across landscapes (Elith and Leathwick 2009; Guisan and Thuiller 2005). These models can illustrate the specific environmental covariates that define a species' habitat and can generate spatial predictions of species' distribution at a landscape scale (Elith and Leathwick 2009). SDMs have also been used extensively to create maps of predicted habitat (Derville et al. 2018; Gantchoff et al. 2019). The new SDMs created by Olson et al. (2021) and Squires et al. (*in prep.*) are based on the best empirical data of lynx locations across the western U.S. The models accurately map environmental covariates (abiotic and biotic features) found at lynx locations, as compared to a random sample of background locations, within and outside of known home ranges in Montana, Washington, Wyoming, and Colorado.

These models provide the predicted relative probability of lynx presence, which here we use as an indicator of habitat suitability. For the purposes of this framework, we use the terms "habitat potentially suitable", "habitat capability" and "habitat quality" to mean the high relative probability of lynx presence or habitat suitability in these areas. It should be noted that these models *do not test occupancy*, and do not evaluate other potential influences on occupancy such as predator and competitor densities, distance to source populations (e.g., Canada), etc. The models indicate that either the abiotic conditions that characterize lynx locations are present ("habitat capability" or "habitat potentially suitable"; Model 30), or that the abiotic and biotic (i.e. current vegetation) covariates that characterize lynx locations are present ("habitat quality"; Model 31) on the landscape. However, though both models may predict the presence of suitable habitat, actual conditions on the ground may not be currently providing the structural characteristics needed by lynx (e.g., high horizontal cover), despite the presence of required environmental covariates.

5.2 Northern Rockies and North Cascades Habitat Modeling

Olson et al. (2021) used data from three geographically distinct areas of residency at the species' southern range periphery in their species distribution model. This included GPS data from 17 individuals in Washington (n=21,518 locations) that were monitored from 2007 to 2013, 66 individuals in Montana (n=164,612 locations) that were monitored from 2004 -2015, and 10 individuals in Wyoming (n=539 GPS locations and n=218 Argos locations) that were monitored from 1996 to 2010. The telemetry data used to create the model was primarily from lynx resident on reproducing territories.

Sixteen climate, topographic, anthropogenic and vegetative environmental predictors that were expected to be related to lynx distribution were selected as covariates. An ensemble-modeling approach was used to develop Species Distribution Models (SDM) for each population and all populations combined; model prediction and transferability were assessed.

Two datasets were used for SDM validation: a withheld set of GPS data not used in the model calibration (hereafter referred to as "W," e.g. W95) and an extensive independent data set from a variety of sources that collectively represented most of the known independent lynx data sources available in the northern Rockies and Cascades of the U.S. (hereafter referred to as "I," e.g. I90). The independent location data for lynx included incidental sightings of animals outside the range of core populations and therefore may represent a larger array of behaviors and thus habitat use, such as denning, incidental sightings, genetic data, camera traps, Argos data from animals moving from Colorado, and mortalities (Olson et al. 2021).

The model accurately delineated large areas of known high-quality contiguous lynx habitat in parts of the Rocky Mountains, the Cascade Range in Washington, and southern British Columbia. Using the regional model, the probability and spatial distribution of habitat that lacked detailed GPS data were also predicted. Thus, the model identified areas that currently support resident lynx populations in the West as well as other areas that may lack recent and/or historical evidence of lynx occupancy but which contain habitat features potentially capable of supporting lynx residency or use. Such areas are important for conservation and management purposes and for prioritizing lynx survey efforts. The model provides consistent predictions of relative habitat quality across multiple jurisdictions, allowing land management decisions to be made and applied consistently over a broad area. It is assumed that by using locations from known home ranges of resident and breeding lynx from multiple areas to develop these habitat models, the spatial variation of both lynx and necessary prey populations (primarily snowshoe hares) is captured.

The model was also adapted for the Southern Rockies ecoregion mapping area, with some variation from the northern model driven largely by differences in available lynx location datasets. The main similarities and differences between the northern and southern modeling and mapping are discussed in more detail in Section 5.3.

In addition to delineating large areas of high-quality contiguous habitat in parts of the Rocky Mountains and the Cascade Range in Washington and British Columbia, the authors were also able to predict areas of potentially suitable habitat outside of the three main population areas including portions of northern Idaho, the Kettle Mountains in Washington, and scattered areas in the Bitterroot and Pioneer Mountains in Montana.

5.3 Approaches to the Northern Rockies / North Cascades and Southern Rockies Habitat Modeling

Although the basic modeling was approached similarly across the western U.S. landscape, some differences were applied to the main SDMs developed for the Northern Rockies / North Cascades and Southern Rockies geographic areas as explained further by Dr. Olson:

"We used the Biomod2 modeling package in the statistical package R software to create both Northern and Southern models. Both models used an ensemble modeling approach; the Northern model used six models in the ensemble (boosted regression trees, multiple adaptive regression splines [MARS], generalized linear models [GLM], generalized additive models [GAM], random forest, and maxent), while the Southern model used five models, dropping the MARS model because it repeatedly failed with this dataset, which we later found to be a problem with the software. Both models used GPS data from resident lynx populations, with the GPS points limited to one point per raster cell to reduce data replication and increase independence.

"In the Northern model, the raster cell size (map resolution) was 250m because of the large spatial extent and the amount of time it took to run models. For the Southern model, since the initial spatial extent was smaller and thus the model run time would be less, we used a smaller resolution of 120m.

"Both models also used only GPS data from lynx resident on primarily reproducing territories; however, the Northern model used data from 93 individuals, from 1996 to 2015, occurring in all months of the year, while the Southern model used data from 18 individuals, from 2010 to 2013, occurring only in winter (Nov-Apr) months, for a total sample size of n=12,105 GPS locations.

"The Southern model also used 13 of the same 16 covariates that were in the Northern model; we did not include heat load or integrated moisture index in the Southern model, since these covariates were shown to have almost no effect on the Northern model (see Figure 7 in Olson et al. 2021), and we were concerned about the time required to create covariates and run models. We also substituted a MODIS-based snow cover layer for snow density in the Southern model since this covariate will be more easily available in Google Earth Engine[2].

"Finally, the independent data the models were tested on varied somewhat, resulting in slightly different versions of model thresholds. In the Northern model, independent data were collected from many sources, including dens, incidental sightings, genetic data, camera traps, Argos data from animals moving from Colorado, a few animals' GPS data that wasn't included in the model, and some mortalities. This resulted in a very broad group of independent data that used a large range of habitat. We therefore created 2 thresholds for the Northern model, one using withheld data from the models, so GPS locations from resident lynx (the 'red' color in Northern maps), and a second threshold using the broad independent data, which resulted in a larger designated area (the 'yellow' area in Northern maps). In the Southern model, the independent dataset was made up of less varied locations, including Argos (n=673) and telemetry (n=3889) data

[2] As part of the project, Drs. Squires and Olson in coordination with our Team are exploring Google Earth Engine as a tool to support the ability for more frequent local updates of lynx habitat maps to reflect ongoing habitat changes over time from wildfires, forest management, beetle outbreaks, and other disturbance agents.

from resident animals >1 yr. post-release, camera traps (n=25), genetic data from snow tracking (n=104), and dens (n=49); all independent data was also only from the winter (Nov-Apr). We created only 1 threshold for the Southern model based on this data, resulting in a habitat boundary that is likely somewhere in between the withheld and independent thresholds for the Northern model. We validated and selected the best-performing Northern model using both withheld and independent data, with three validation metrics: area under the curve (AUC), a continuous Boyce index, and a minimum predicted area. Southern models were validated on independent data only using methods developed by Boyce et al. (2002) and adapted by Holbrook et al. (2017), which divide the entire study area into equal area bins and then determine how many bins are necessary to capture 90% of lynx locations; model selection for Southern models was based on this validation and expert opinion."

6. APPLICATION OF THE NEW MODELS

The Olson et al. (2021) and Squires et al. (*in prep.*) models and regional lynx habitat maps represent a significant advancement in our understanding of potential habitat suitability for the Canada lynx in the western U.S. The studies represent the most comprehensive evaluation of lynx habitat in the western U.S. and provide highly predictive models of lynx habitat, validated using withheld and independent data. These models create a refined depiction of lynx habitat that will facilitate the application of conservation management to areas that are most relevant to Canada lynx. They therefore became the starting point of the new lynx conservation and recovery framework.

The Olson et al. (2021) study revealed that lynx habitat is made up of a complex variety of environmental conditions, that can be modeled with covariates independent of primarily vegetation type, structure and composition and elevation as the existing maps are based upon. The species distribution model in this study is derived from location data of telemetered lynx (see section 5.2 for number of lynx and locations). Lynx habitat was best predicted by a compilation of 12 climate and topographic variables, 2 anthropomorphic and 2 vegetative covariates, resulting in a map of lynx habitat that in some areas differ substantially from the existing maps used in the NRLMD, SLRA, and LCAS that determine where lynx habitats are managed on National Forest System lands. The covariates that had the most effect on predicted habitat suitability were primarily temperature and moisture related, with the top four variables all related to snow, precipitation, or cold temperatures. NDVI (normalized difference vegetation index), which is a measure of long-term forest presence or productivity, was the 5th most important variable. Specific vegetation communities or habitat types were not used in the model. Landcover classification variables that covered both the U.S. and Canada were not available. Instead, continuous variables (NDVI and a metric of forest heterogeneity) that were related to vegetation communities were used, which were more informative because they were direct measures of environmental conditions, rather than categories based on other modeled outputs (Olson, *pers. comm.*).

The WLBT used science-based understanding of lynx habitat distribution developed by Olson et al. (2021) and Squires et al. (*in prep.*) to identify key conservation areas from the lynx species distribution models' predictions of habitat capability across Federal lands in the Northern and Southern Rockies and North Cascades. The team attempted to spatially delineate the following:

- Habitat with the highest potential for supporting long term lynx occupancy and reproduction (referred to as Tier 1 habitat).
- Habitat with the potential to support lynx occupation and promote connectivity that is located between Tier 1 habitat areas, and that provides habitat redundancy on the landscape in the face of uncertainties of climate change and possible periodic irruptions of dispersing lynx into the northern contiguous U.S. from source populations in Canada (referred to as Tier 2 habitat).
- Habitat that would provide foraging opportunities and shelter for dispersing or transient lynx (referred to as Tier 3 habitat).

Lynx habitat is particularly sensitive to climate change, as temperature and snowpack are important environmental components that impact the distribution of cool, moist subalpine forests. With climate warming modeled to continue and accelerate through the end of the century, lynx habitats are expected to contract northward and to higher elevations (where possible). Further, lynx habitat is also vulnerable to increased frequency, extent, and intensity of wildfire and forest insect outbreaks associated with climate warming.

Our objective was to define a new, science-based framework for identifying lynx habitat and its vegetation characteristics for lynx conservation and management containing a landscape matrix of modeled high and moderate quality habitats as follows:

1. Large and well-connected areas of high-quality habitat that can support lynx occupancy and persistent resident breeding populations (Tier 1).
2. General large (but smaller than Tier 1 areas) and/or more disjunct areas with lower proportions of high-quality habitat that may support occasional/temporary lynx residency and dispersal, but may not have a known history of occupation and may not support reproduction or persistent occupancy (Tier 2).
3. Smaller, scattered areas of habitat that may function as "stepping stones" to facilitate dispersal and foraging between Tier 1 and Tier 2 areas or in known connectivity hotspots, but are unlikely to support residency or reproduction (Tier 3).

6.1 Refined Lynx Habitat Mapping

Our lynx habitat mapping efforts for the western U.S. consists of two primary regions encompassing the northern and southern ranges and habitats of the Canada lynx in the western United States.

6.1.1 Northern Rockies, North Cascades, Utah, & Bighorn Mountains

The Northern Rockies & North Cascades geographic area in our project includes portions of Wyoming, northern Utah, Montana, Idaho, and Washington.

6.1.2 Southern Rockies

The Southern Rockies geographic area in our project includes southern Wyoming, Colorado, and northern New Mexico.

6.2 Identification of Lynx Conservation Areas from the New Habitat Models

For the purposes of focusing more effective lynx habitat management and conservation of a wide-ranging species like lynx, the WLBT wanted to identify key conservation and recovery areas. To do this, we identified discrete habitat polygons from within the continuous surface of predicted lynx habitat probablilty presented in Olson et al. (2021). We targeted high probability habitat areas defined by the selected models (what this Framework refers to as *high-quality habitat*) that would provide the highest conservation value for lynx. With the assistance of specialists from the USFS Northern Region's Geospatial Program, a GIS process was developed that enhanced our ability to identify discrete areas of high quality habitat. This process allowed the WLBT to distinguish contiguous areas of high quality habitat based on the categorical spatial predictions of lynx relative habitat probability modeled by Olson et al. (2021), and to select habitat capability thresholds, patch sizes, and patch buffer values to locate and map discrete habitat polygons. The habitat values we selected and analyzed are described in the following sections.

6.2.1 Thresholding

Canada lynx are observed in a variety of habitat types, including those where conservation efforts would be ineffective (e.g., low elevation dry forests, non-forested areas). Thus we needed to select a threshold that would accurately capture a high proportion of areas of known lynx home ranges and verified lynx location data while excluding areas of low conservation value. To accomplish this goal, we selected the thresholds described by Olson et al. (2021) that captured 95% of the withheld lynx GPS locations and 90% of the independent data points. We assumed these independent data would be more variable (thus a lower threshold) than withheld data because they include observations of dispersing lynx traversing non-typical habitat. This threshold (W95/I90) captures most of the high-quality habitat that lynx would potentially use within the larger landscape. We also evaluated the threshold of 85% of the withheld lynx GPS locations and 90% of the independent data (also reported in Olson et al. 2021) to represent areas that lynx most frequently used and had the highest potential habitat quality. However, the W85/I90 threshold created a map with fragmented habitat areas and didn't include connecting areas of potential high use by lynx.

6.2.2 Patch Size

Next, we applied a minimum patch size to delineate areas with the highest likelihood of supporting multiple home ranges of resident and/or breeding lynx. We used the Garnet Mountains in Montana as an example of one of the smallest known occupied areas that could sustain a small group of lynx. The Garnets have historically supported 5-10 individuals (including both males and reproducing females), with some male home ranges that overlap multiple female home ranges. The Garnet Mountains where this group of home ranges occur includes approximately 20,000 acres of modeled lynx habitat. Thus, we used this discrete group of Garnet Mountain lynx as a surrogate measure for establishing a minimum size for areas of high quality habitat that we believe capable of supporting multiple lynx home ranges. We then used the GIS process described above, this 20,000-acre minimum patch size, and the W95/I90 habitat quality threshold described previously to idenfify and map areas of contiguous high quality habitat capable of supporting resident and/or breeding lynx.

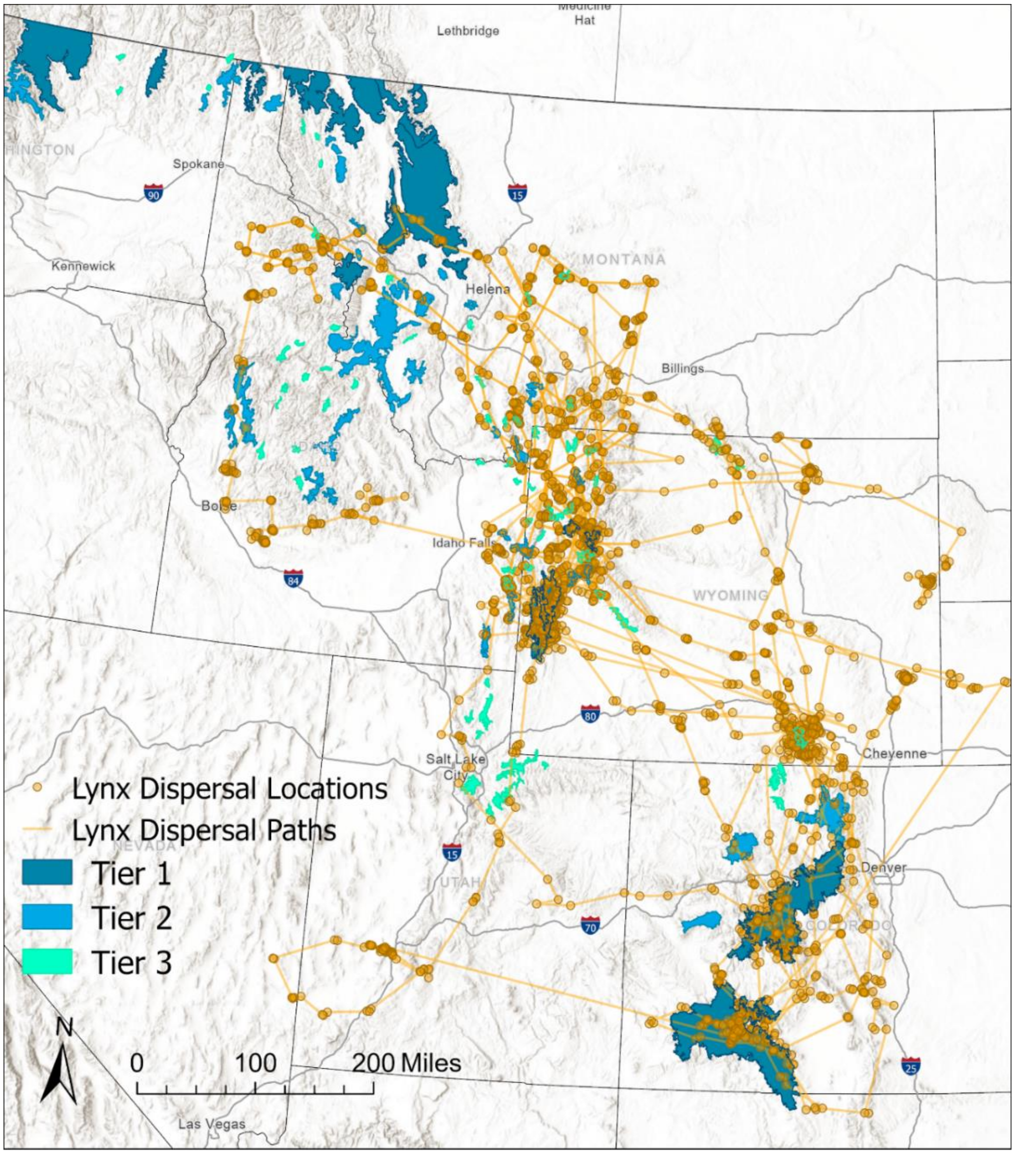
6.2.3 Habitat Quality

Finally, to further refine our approach for informing a tiered conservation and management framework (Section 6.3), we established levels of how much of the highest-quality habitat would be appropriate in each mapped polygon to meet the objectives of each tier. Based on our analysis of data from the home ranges of reproducing females, areas containing greater than or equal to 50% of highest-quality habitat (the 85W threshold described in Olson et al. 2021) have the best potential to support reproduction. We expect that habitat of this quality would reflect the full range of structural conditions used by resident lynx in their home ranges and would promote successful reproduction (Kosterman et al. 2018, Holbrook et al. 2019). Many areas currently known to contain these habitat conditions support resident and breeding lynx, but some may be currently unoccupied.

6.2.4 Stopover Areas

To facilitate movement between fragmented areas of high quality habitat, we again used the GIS process we developed, this time to identify other, smaller habitat patches that are capable of providing high quality foraging opportunities and cover for transient and dispersing lynx (termed “stopover” areas). These identified areas are typically between 10,000 and 20,000 acres in size and contain moderate to high quality modeled habitat. A lower bound of 10,000 acres was deemed a reasonable size that could support lynx foraging without introducing too much complexity (many small areas) to implement across the landscape. Most delineated stopover areas include contiguous high quality habitat, but some were delineated by applying a 500-meter buffer to capture adjacent disjointed fragments of habitat and consolidating those pieces to delineate an area of 10,000 to 20,000 acres. Although lynx are capable of long-distance movements across a variety of terrain and habitats (Buderman et al. 2018; Squires et al. 2003; Mowat et al. 2000; Ivan 2012, 2017, 2019; Devineau et al. 2010), access to forested habitats that contain their preferred prey species would provide efficient foraging opportunities during exploratory or dispersal movements. Lynx are known to forage in small patches of dense spruce-fir forest in Wyoming, Montana, and Colorado (John Squires, *pers. comm.*, Ivan and Shenk 2016) and to use even small and disjunct patches of residual unburned forest within large fire perimeters (Vanbianchi et al. 2017). Therefore, the team delineated these stopover areas to support lynx navigation of broad landscapes and to maintain or restore the permeability of these landscapes for dispersing lynx. Evaluation of the Colorado lynx long distance movement data provided in reports by Ivan (2012, 2017, 2019) for Montana, Wyoming, and Utah show lynx traveled to areas of moderate to high quality habitat as defined by (Olson et al. 2021, Colorado Parks and Wildlife, unpublished data, 1999-2011) as they moved across the broader Rocky Mountain landscape (See Fig. 1). We assume such pathways may support connectivity for natural dispersal between the Northern and Southern Rockies in the future.

Figure 1. Locations and long distance movement paths of collared Canada lynx that were part of Colorado's reintroduction program, in relation Western Lynx Biology Team delineated areas of high conservation value (Colorado Parks and Wildlife, unpublished data, 1999-2011). (Please refer to Section 5.5 (Mapping Results) for information about how the WLBT delineated areas of high conservation value.)



6.3 Further Refinement of Maps

The Team refined the areas created from the model outputs and the previously described GIS process by using additional relevant information available to us. The information included other verified lynx occupancy and/or locations and habitat in places where (1) more refined resource selection function modeling was previously completed but at smaller spatial scales (Squires et al. 2010, 2013; Holbrook et al. 2017), (2) snowshoe hare surveys or density estimates had previously been completed, (3) known or current / recent occupation by lynx, (4) ground-truthing by Team members or forest biologists indicated potential habitat capability that may not have been picked up by the our GIS process or were not captured in the distribution model, and (5) distance from Canada border and core populations. The Team also used this information to exclude some peripheral areas that would be unlikely to support lynx residency, provide connectivity, or contribute in any meaningful way to regional lynx conservation, and those areas were not included in the map.

6.4 Team Application and Refinement of the New Model

6.4.1 Northern Rockies & North Cascades – Models 30 and 31

In collaboration with Drs. Squires and Olson, the WLBT used a combination of two variations of the SDM to generate the foundational habitat surface for the Northern Rockies and GYA, and North Cascades geographic area. This approach provided more flexibility to calibrate habitat polygons on the map surface across such a large geographic area consistent with our objectives and to refine the fit of modeled vs. actual habitat conditions for which we had additional knowledge.

SDM Model 30 is the regional model as described in Olson et al. (2021) with 16 covariates. SDM Model 31 did not contain the vegetation covariates of normalized difference vegetation index (NDVI) and forest heterogeneity (standard deviation of percentage of tree cover), nor the anthropogenic covariates of road density and light index (relative intensity of remotely sensed lights at night). The use of the two models has tradeoffs in habitat estimation. Model 30 underestimates habitat in areas that have had recent fires or recent regeneration harvest, but still have habitat potential, and tended to more accurately identify alpine areas (i.e., high rocky areas with limited conifer cover), and natural meadows. Model 31 overestimates habitat in alpine areas and natural meadows but is more accurate in predicting habitat capability in recently-burned areas. The area of alpine and open areas is much smaller than the area of fires in either model, so potentially overestimating alpine was much less of a concern than underestimating habitat potential remaining in areas burned in past wildfires.

The Team used a combination of both models to delineate discrete habitat areas for lynx conservation moving forward. Model 31 ensured that burned habitat/areas of habitat potential were fully accounted for, while Model 30 added a vegetation component to make sure alpine and natural meadow areas were not identified as lynx habitat. We typically started with Model 31, accepting some over estimation of habitat in alpine areas, to fully account for burned areas with habitat potential. We then fine-tuned the area with Model 30, using the overlapping areas of the two models to validate areas identified as high-quality habitat, and to minimize over-mapping alpine areas. There were some habitat areas where Model 30, with its vegetation covariates, appeared to better capture habitat and/or lynx history in a localized area based on additional information and Team members' experience in those areas.

6.4.2 Utah and the Bighorn Mountains

The state of Utah and the Bighorn Mountains in Wyoming have limited verified records of lynx presence historically (McKelvey et al. 2000, in Ruggiero et al. 2000), and of temporary occurrence of Colorado-released lynx as recently as 2006 in the Bighorns (Ivan 2017) and 2010 in Utah (Ivan 2019). As documented by these data, Utah and the Bighorn Mountains have habitat that has been used by lynx temporarily. There is no known long-term occupancy of these areas by the Canada lynx and they are isolated from occupied lynx habitat and to northern populations in Canada. For further description of lynx habitat and management in Utah and the Bighorn Mountains, please see Appendix A.

6.4.3 Southern Rockies– Model 10a

Similar to the Northern approach, the modeling and mapping for the Southern Rockies geographic area initially involved development of several model iterations and expert review by lynx researchers. Results of all models were strong and performed exceptionally well in capturing the independent location data and predicting potentially suitable lynx habitat and use.

Expert review of the various maps was used to select which appeared overall to best capture known lynx locations and habitat conditions in the Southern Rockies. Our expert review included Drs. Olson and Squires with USFS Rocky Mountain Research Station, Dr. Jake Ivan with Colorado Parks & Wildlife, Dr. Joe Holbrook with University of Wyoming, and Peter McDonald, USFS Region 2.

Model 10a (model names are arbitrary and refer to the model development process) was selected because it appeared to best align lynx and habitat predictions with our knowledge of actual habitat distribution and lynx residency in the Southern Rockies. Both biotic (included NDVI) and abiotic versions of Model10a were developed.

The biotic version of Model 10a was selected, because it was more applicable to an investigation led by Dr. Squires on the effects of past natural and anthropogenic disturbance on these newly-defined high-quality habitat areas in the Southern Rockies. Supporting our decision was the fact that the two versions of the 10a map outputs were relatively similar visually and in total area of high-quality habitat for the Southern Rockies geographic area (biotic = 4.30 mil. acres; abiotic = 4.27 mil. acres). An initial overlay of the recent fire history from 1984 - current also indicated wildfires have not yet extensively impacted these high-quality habitat areas (John Squires, *pers. comm.*). Hence, we were not as concerned about the biotic model overlooking areas of high habitat potential that have burned in the recent past.

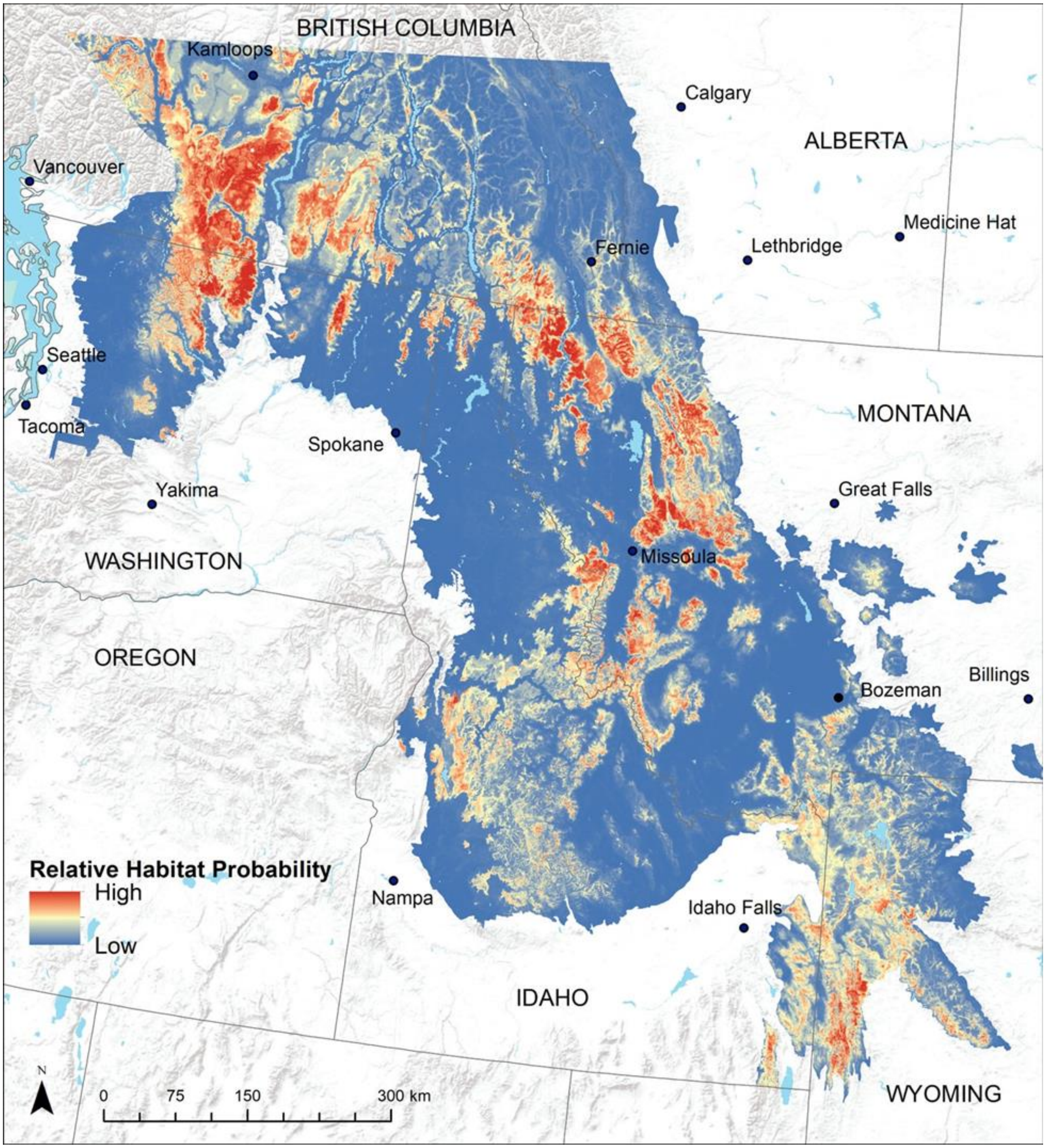
6.5 Mapping Results

Existing mapped lynx habitat includes approximately 28 million acres in the western U.S. Our revised spatial framework would focus Canada lynx conservation and management in the areas illustrated in the following figures. We expect our refined maps will reduce the area where focused management direction to conserve/recover lynx populations is appropriate by 40 - 50% compared to existing maps of lynx habitat across the Northern Rockies, extending to the

Greater Yellowstone Area, Northern Cascades, and the Southern Rockies, although the direction and extent of changes will vary from one area to the next.

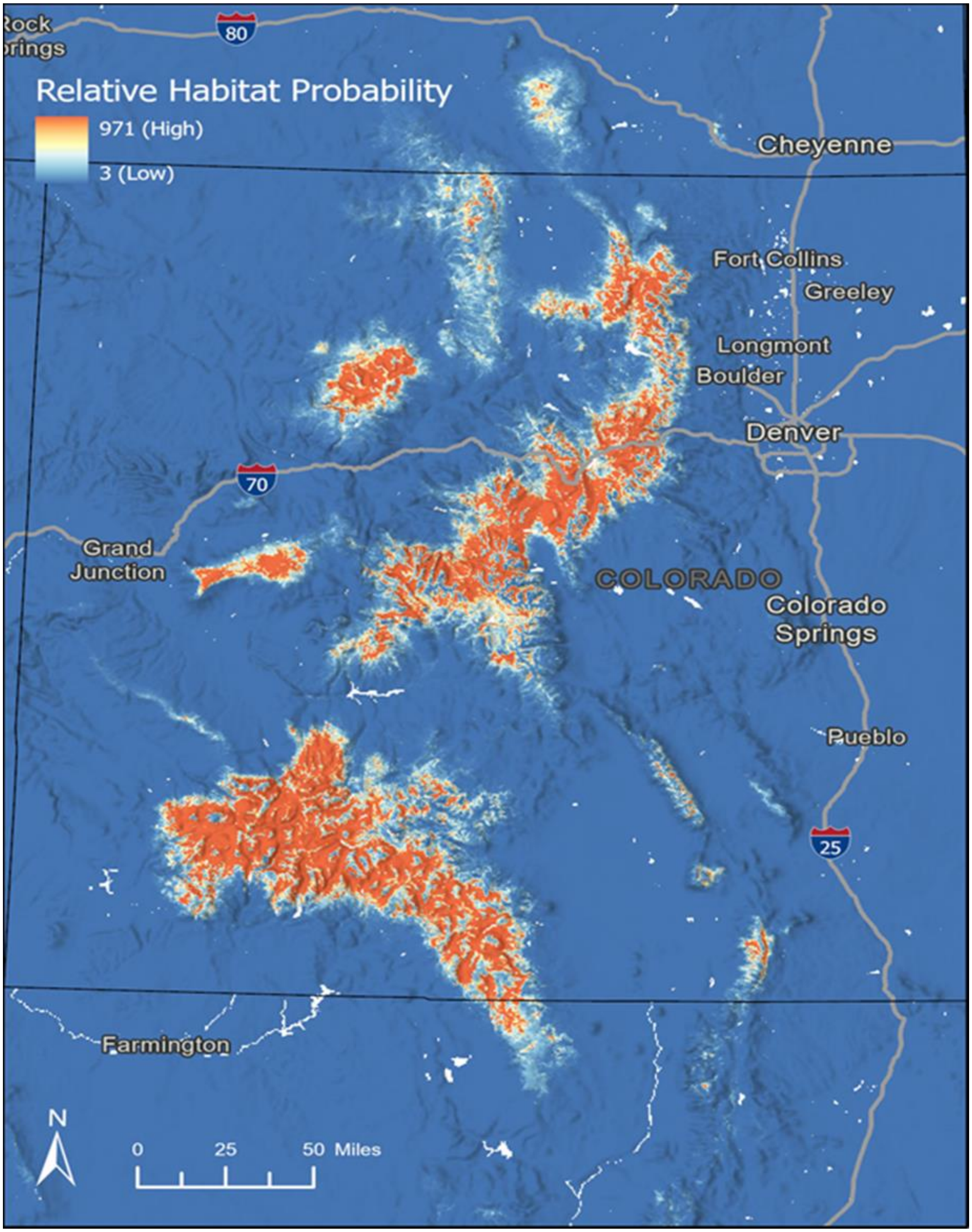
6.5.1 Northern Rockies and North Cascades

Figure 2. Spatial predictions of Canada lynx relative habitat probability on continuous scale across the northwest US (Olson et al. 2021, Figure 6).



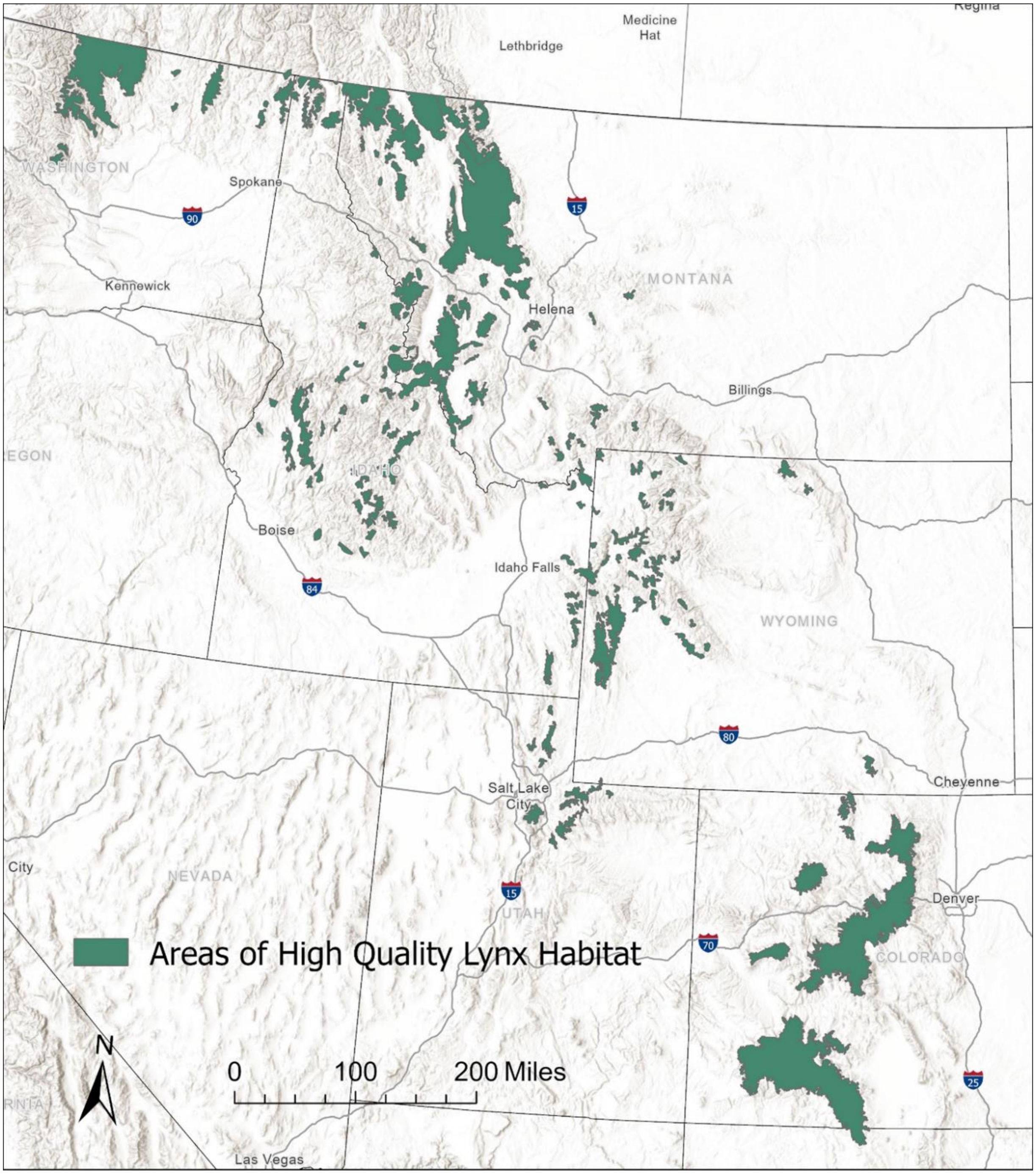
6.5.2 Southern Rockies (southern Wyoming, Colorado & northern New Mexico)

Figure 3. Spatial predictions of Canada lynx relative habitat probability on a continuous scale across the southern Rocky Mountains (Squires et al. *in prep.*).



6.5.3 Distinct units of high-quality habitat from the continuous predictive model.

Figure 4. Areas of high conservation value for the Canada lynx in the western U.S. as delineated by the Western Lynx Biology Team using the best available science on lynx distribution and habitat use. Delineated areas included higher-capability habitat within modeled areas of habitat greater than 20,000 acres (10,000-20,000 acres for stopover areas) selected to include 95 percent of withheld lynx GPS locations and 90% of the independent data (See Section 6 for process details).



7. MANAGEMENT

7.1 A Tiered Approach

7.1.1 Functional Role of Tiers

Lynx within the contiguous United States are at the very southern limit of their distribution. Olson et al. (2021) provided an empirically driven predictive map of lynx habitat in a continuous surface of habitat probabilities based on actual telemetry data from lynx on home ranges, and extensively tested and validated by an independent data set of lynx locations from a variety of sources. This map more accurately reflected lynx habitat use than previous habitat mapping efforts that are based on vegetation type and elevation (Section 4). To create a lynx conservation and recovery framework for these habitat areas, we transformed the continuous predictive model into discrete units of potential habitat. We developed a tiered approach, identifying areas, or tiers, capable of supporting lynx in three different functional roles.

These tiers are different from the three categories used in previous conservation efforts that have mapped lynx habitat based on lynx occurrence, reproduction, and persistence. The Draft Recovery Outline (U.S. Fish and Wildlife Service 2005) and the LCAS (Interagency Lynx Biology Team 2013) used a 3-category approach that included Core, Secondary, and Peripheral areas. These areas were mapped based on historical evidence of lynx occurrences. In other words, they were based on where lynx were known to occur or to have occurred in the past. In the Draft Recovery Outline and LCAS, the three categories were described as such:

- Core areas-- those with evidence of long-term, persistent, reproducing populations of lynx.
- Secondary areas-- those with evidence of historical lynx occurrence but not of reproduction or persistent lynx occupancy.
- Peripheral areas-- those with evidence of sporadic lynx occurrence that usually corresponded to cyclic population highs in Canada and had no evidence of reproduction or persistence.

While the functional roles of these areas may seem similar to the roles of the categories we identified, the underlying data used to identify and map the categories in our effort differ from those used to map areas used in the Draft Recovery Outline and LCAS. In contrast to the past efforts, in this framework we mapped areas where the habitat (including biotic and abiotic factors) indicates capability of supporting lynx in three different functional roles, regardless of whether lynx have been detected there in the past or whether lynx were known to have used the areas. By including areas that were predicted by lynx distribution models (Olson et al. 2021, Squires et al. *in prep.*) to be capable of supporting lynx, but were outside known populations, land management decisions can be made consistently over a broad area across multiple jurisdictions in those areas most relevant to lynx. Because of these important differences, we chose to use the Tier 1, 2, and 3 nomenclatures rather than the nomenclature from the previous efforts.

7.1.2 Tier Objectives and Attributes

7.1.2.1 TIER 1

The role of Tier 1 areas is to provide large and well-connected areas with high proportions of high-quality habitat. The objective is to maintain habitat conditions that would support consistent occupancy and provide for persistent breeding populations. The desired vegetation structural mosaic in Tier 1 areas reflect the conditions in home ranges of female lynx known to be successful at producing litters.

- Generally large areas of contiguous habitat;
- >20,000 ac., generally >50% highest probability modeled habitat;
- In close proximity to source populations in Canada or other Tier 1 areas (with the exception of the greater Yellowstone Area or Colorado, which have recent or current occupation);
- Provides landscape level connectivity between other Tier 1 and Tier 2 areas.

7.1.2.2 TIER 2

Tier 2 areas contain lower proportions of high-quality habitat that provide habitat for expansion or redundant habitat areas. In Tier 2, the objective is to provide habitat to support periodic to regular occupancy, which may include reproductively successful individuals at times. The desired vegetation structural mosaic in Tier 2 areas reflect the range of conditions within known home ranges of male and female lynx.

- Generally large areas of contiguous habitat;
- >20,000 ac., generally <50% highest probability modeled habitat;
- Generally, in close proximity to source populations;
- Provides landscape level connectivity between Tier 1 areas for dispersal and genetic exchange.

7.1.2.3 TIER 3

The role of Tier 3 is to maintain connectivity and facilitate dispersal across the landscape and among tiers. In Tier 3, the objective is to provide habitat to support periodic use by lynx during dispersal, and perhaps temporary occupancy. The vegetation structural conditions reflect habitat that provides for high quality foraging opportunities and shelter.

- Smaller, well distributed islands that may function as “stepping stones” for dispersing lynx;
- Generally, 10,000 – 20,000 acres, however occasionally larger
- Provides landscape level connectivity between Tier 1 and Tier 2 areas for dispersal and genetic exchange.

7.1.3 Desired Vegetation Structural Characteristics for Tier 1, 2, and 3 Habitats

In the western U.S., lynx habitat is characterized by dense horizontal cover, persistent snow, and moderate to high snowshoe hare densities located in gentle, rolling topography (Maletzke et al. 2008, Interagency Lynx Biology Team 2013, Squires et al. 2013). Engelmann spruce, subalpine fir and lodgepole pine forest cover types occurring on cold, moist potential vegetation types provide habitat for lynx (Aubrey et al. 2000). Recently published scientific research on Canada lynx habitat use and population demography describe the specific vegetation characteristics found in the home ranges of reproductive and nonreproductive male and female lynx. (Holbrook et al. 2017, Kosterman et al. 2018, Holbrooke et al. 2019). These structurally based characteristics can be adapted to specific vegetation management objectives that can be evaluated, designed, and implemented. Using these objectives, along with current management direction, habitat can be maintained or restored to the desired forest conditions over time in the areas of highest value to lynx.

Recommendations for *amounts* of forest structural classes at the home range scale were derived primarily from Holbrook et al. (2017). The *definitions* for each structural class referenced in the vegetation structural mosaics above are taken from Holbrook et al. (2019) (Fig. 3) as:

> *Stand Initiation:* Stands with few trees and an open canopy. Median basal area weighted DBH was 0 inches (0 - 8), canopy cover was 8% (0 - 36), and tree density >5 inches was 0 trees/acre (0 - 75). n = 37 plots.
>
> *Sparse:* Stands with larger trees but an open canopy. Median basal area weighted DBH was 6 inches (0 - 11), canopy cover was 28% (8 - 49), and tree density >5 inches was 48 trees/acre (0 - 144). n = 172 plots.
>
> *Advanced regeneration:* Stands with many trees and a dense canopy. Median basal area weighted DBH was 8 inches (5 - 10), canopy cover was 45% (30 - 70), and tree density >5 inches was 167 trees/acre (72 - 289). n = 67 plots.
>
> *Mature:* Stands with many trees and a mulit-layered canopy. 30% of the trees were classified as > 120 years old. Median basal area weighted DBH was 10 inches (7 - 14), canopy cover was 56% (40 - 70), and tree density >5 inches was 217 trees/acre (144 - 331). n = 274 plots.

It is important to note that existing lynx management direction and procedures for Federal agencies will continue to apply until that direction is modified as needed to better align with the key new science reflected in our revised lynx habitat map and new conservation recommendations. In general, Federal land management agencies in the Western U.S. either operate under lynx-specific direction that has been incorporated into Forest Plans and must be followed, and/or they consider the LCAS in their management actions (see Appendix C for more details on current lynx habitat management direction). We expect that some of the existing direction will need to be changed and/or supplemented given the substantial nature of the new science and this Framework for mapping and managing lynx habitat.

7.1.3.1 TIER 1

The desired vegetation structural mosaic provides high-quality habitat capable of maintaining consistent occupancy and persistent breeding populations through time. In general, lynx use a landscape that is dominated by abundant and well-connected mature, multi-storied forests composed primarily of Engelmann spruce and subalpine fir habitat types, which can also include a lodgepole pine component, within a habitat mosaic of forest structure that includes patches of advanced regeneration.

Desired Vegetation Structural Mosaic

The desired vegetation structural mosaic for mapped lynx habitat at the home range scale[3] includes:

Mature Forest

50-60% mature forest[4] which contains:

- 90% of the mature forest should have dense horizontal cover to provide foraging habitat. Please see definitions below for dense horizontal cover.
- Stands of mature forest with dense horizontal cover are well-connected[5]

Dense Horizontal Cover

Definitions for dense horizontal cover may vary by regional area and by the time of year in which horizontal cover is measured. Forest horizontal cover is necessary to support abundant populations of snowshoe hares that are preferred prey of lynx. In general, in all areas, higher quality lynx foraging habitat is associated with more dense horizontal cover (50-70% horizontal cover).[6] However, stands averaging less dense horizontal cover (30-50%) can also provide suitable foraging habitat for lynx depending on how the patchy distribution of cover impacts patterns of snowshoe hare abundance (Holbrook et al. 2016, Savage et al. 2015, Holbrook et al. 2017). For specific regional and seasonal horizontal cover ranges, see below.

- Montana/Northern Idaho/Washington: (Maletzke 2004, Walker 2005, Squires et al. 2010,)

[3] Lynx Analysis Units (LAUs) can be used as a surrogate for lynx home ranges.

[4] Mature forest as modeled by Savage et al. (2018) and defined in Holbrook et al. (2019).

[5] This can be interpreted as the average distance an animal could travel within each female's core area without leaving mature forest, starting from a random point and moving in a random direction (e.g., Kosterman et al. 2018, Holbrook et al. 2019); The WLBT will work on a methodology for determining/measuring connected mature forest at the home range scale.

[6] Dense horizontal cover (measured during summer): In lynx home ranges in Montana, 70% of mature forest stands contained horizontal cover >50%; 91% of mature forest stands contained high horizontal cover >40%.

    - Measured in winter: greater than 30%
    - Measured in summer: greater than 40%
- Southeast Idaho, Wyoming, Colorado, Utah: (Berg 2010, Ivan et al. 2014)
    - Measured in winter or summer: greater than 30%.[7]

Advanced Regenerating Forest

- At least 20% advanced regenerating forest[8] that provides winter snowshoe hare habitat (see description of winter snowshoe hare habitat below).
- Additional amounts of advanced regenerating forest providing winter snowshoe hare habitat greater than 20% may be beneficial, where mature stands with high horizontal cover are limited and need to develop the amount of forest in the advanced regeneration structure class in the home ranges of productive females typically range between 9-33% (Holbrook et al 2019).

Winter snowshoe hare habitat:

Snowshoe hares use both mature closed-canopy forest and regenerating stands of various species (Hodges 2000a, 2000b). Snowshoe hares primarily occupy areas with substantive understory cover (Hodges et al. 2009), and the amount and density of horizontal cover strongly influences snowshoe hare abundance (Interagency Lynx Biology Team 2013). Dense horizontal cover likely reduces exposure to predators and provides better access to food resources and thermal protection during the critical winter period (Hodges et al. 2001). In winter, horizontal cover is provided from conifer boughs touching the snow surface (Squires et al. 2010), as well as vegetation in regenerating stands that extends above snow cover. In the western U.S., cover types that support snowshoe hares include Engelmann spruce, subalpine fir, mixed spruce-fir, mixed aspen and spruce-fir, and mixed spruce-fir and lodgepole pine (Hodges 2000b, Zimmer 2004, Zahratka and Shenk 2008, Berg et al. 2012, Ivan et al. 2014). Snowshoe hares eat twigs, buds, and bark (Hodges 2000a) and lodgepole pine is a preferred food source in winter months due to higher nutritional value (Holbrook et al. 2016, Kurzen 2019).

Other Structural Conditions

No more than 30% in structural classes that do not provide winter snowshoe hare habitat[6]. Structural classes that do not provide winter snowshoe hare habitat may include: 1) stand initiation in which trees do not yet protrude above the snow and do not provide sufficient

[7] The revised forest plan for the Rio Grande National Forest plan utilized results from recent lynx and snowshoe hare studies on and near the forest to inform somewhat different dense horizontal cover objectives specific to that national forest.

[8] Advanced regenerating forest: as modeled by Savage et al. (2018) and defined in Holbrook et al. (2019).

amounts of dense horizontal cover to support snowshoe hare during winter; 2) sparse forest, as modeled by Savage et al. (2018) and defined in Holbrook et al. (2019); and 3) high elevation alpine forest, talus slopes, etc., as modeled by Savage et al. (2018).

Conservation Measures

Strive to maintain or manage toward 60% mature forest within LAUs.

The intent is to maintain suitable foraging habitat in all areas and enhance it where feasible to promote higher amounts of high-quality foraging habitat.

When assessing mature stands for lynx foraging suitability:

- Generally, within mature stands the higher the horizontal cover, the better.
- Horizontal cover amounts of 50% or greater provide the highest quality foraging habitat; however, stands with 30-50% horizontal cover also contribute to foraging habitat for lynx (see definition above)

For Tier 1 areas that **do not** meet the desired vegetation structural mosaic specified above, silvicultural actions may be appropriate to enhance the development of forest structural classes to meet desired vegetation characteristics/mosaics above.

For Tier 1 areas that **do** meet the desired vegetation structural mosaic specified above, a maintenance strategy could involve a cohesive silvicultural system for sustaining the desired vegetation characteristics over the long term (e.g., >200 years).

7.1.3.2 TIER 2

The desired vegetation structural mosaic provides high-quality habitat capable of supporting lynx residency, dispersing individuals, and possible reproduction. In general, lynx use a landscape that is dominated by abundant mature, multi storied forests composed primarily of Engelmann spruce and subalpine fir habitat types within a habitat mosaic of forest structure that includes patches of advanced regeneration. With exceptions, Tier 2 areas generally contain lower amounts of high-probability modeled habitat than Tier 1. Tier 2 areas could support range expansion or colonization of individuals from Tier 1 habitats and provide habitat redundancy across the landscape over the long term.

Desired Vegetation Structural Mosaic

The desired vegetation structural mosaic for mapped lynx habitat at the home range scale[3] include:

Mature Forest

No less than 50% mature[4] forest.

Dense Horizontal Cover:

90% of the mature forest should have dense horizontal cover to provide foraging habitat. Please see definition above for dense horizontal cover.

Advanced Regenerating Forest

- At least 20% advanced regenerating forest[8] that provides winter snowshoe hare habitat (see horizontal cover definition above).
- Additional amounts of advanced regenerating forest providing winter snowshoe hare habitat greater than 20% may be beneficial, where mature stands with high horizontal cover are limited and need to develop.

Other Structural Conditions

- No more than 30% in structural classes that do not provide winter snowshoe hare habitat[6] (see above).

Conservation Measures:

The intent is to maintain suitable foraging habitat in all areas and enhance it where feasible to promote higher amounts of high-quality foraging habitat.

When assessing mature stands for lynx foraging suitability:

- In general, within mature stands the higher the horizontal cover, the better.
- Horizontal cover amounts of 50% or greater provide the highest quality foraging habitat, however, stands with 30-50% horizontal cover also contribute to foraging habitat for lynx (see definition above).

For Tier 2 areas that **do not** meet the desired vegetation structural mosaic specified above, silvicultural actions may be appropriate to enhance the development of forest structural classes to meet desired vegetation characteristics above.

For Tier 2 areas that **do** meet the desired vegetation structural mosaic specified above, a maintenance strategy could involve a cohesive silvicultural system for sustaining the desired vegetation characteristics over the long term (e.g., >200 years).

The desired vegetation structural mosaic in these areas provides foraging opportunities and resting areas for transient or dispersing lynx as well as connectivity across the landscape and between Tier 1 and Tier 2 areas.

7.1.3.3 TIER 3

Desired Vegetation Structural Mosaic

The desired vegetation structural mosaic for mapped lynx habitat within Tier 3 areas include:

- Foraging habitat should provide dense horizontal cover (see definition above), within mature forest and advanced regeneration stands that are generally adjacent or in close proximity to each other.
- The mosaic of mature and advanced regeneration should be at least 30 to 50% mature and at least 20 to 30% advanced regeneration.
- Managing at higher levels of mature and advanced regeneration provide the best foraging opportunities.

Conservation Measures:

Larger areas of mature and advanced regeneration forest provide the best foraging habitat. However, stands of mature and advanced regeneration forest with high horizontal cover as small as approximately 8-12 acres distributed throughout the Tier 3 area will also provide foraging habitat (Squires *pers comm.*, Ivan and Shenk 2016). These small patches are particularly important when there is less than 30% mature forest or 20% advanced regeneration with high horizontal cover within the Tier.

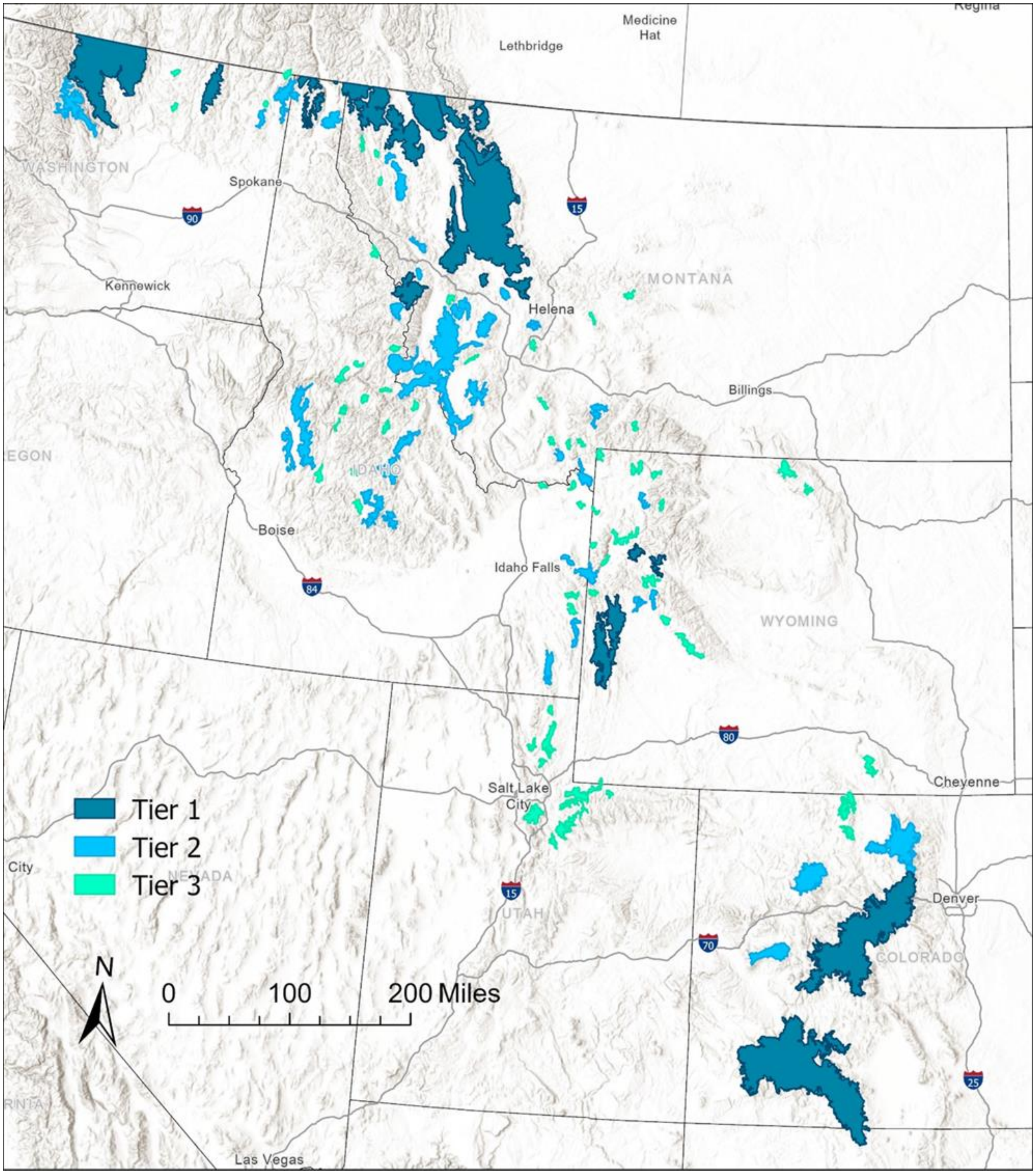
Management practices that encourage dense understory within forest stands should be prioritized in Tier 3.

For Tier 3 areas that **do not** meet the vegetation desired structural mosaic specified above, silvicultural actions may be appropriate to enhance the development of forest structural classes to meet desired vegetation characteristics above.

For Tier 3 areas that **do** meet the desired vegetation structural mosaic specified above, a maintenance strategy could involve a cohesive silvicultural system for sustaining the desired vegetation characteristics over the long term (e.g., >200 years).

7.1.4 Final Habitat Map with Tier Assignments

Figure 5. Tier assignments of high-quality habitat based on conservation objectives.



7.2 Adaptive Management

Habitat conditions change over time due to natural forest dynamics, as well as from disturbances from wildfire, insect infestation, etc., and the response of lynx to regional-scale stressors is largely unknown. In the face of such uncertainty, an adaptive management process will be needed to maintain or develop the specific habitat conditions that lynx prefer across the landscape where good potential exists.

Adaptive management is a structured, iterative process. In this framework, we have evaluated the most recent scientific research on Canada lynx habitat use and distribution, developed a map of areas likely to be of most conservation value to lynx, and identified the goals of vegetation management within those areas. The next steps are to use this information to develop management direction to implement those goals and objectives, monitor the impacts of management, evaluate those monitoring results, and then modify management as needed to respond to changing conditions in a meaningful timeframe.

Key questions and metrics of success should be identified to guide a monitoring program and associated adaptive management. Coordination and collaboration across agencies, research institutions, and land ownerships is needed to develop and implement a post-implementation monitoring program, with the results to be evaluated and used in an adaptive management context.

As future trends in lynx habitat remain uncertain, particularly in relation to changing biophysical conditions, habitat monitoring over time becomes essential, both in managed and unmanaged habitats. While monitoring a rare, wide-ranging carnivore such as lynx can be difficult and expensive, monitoring techniques are available that make this feasible.

In addition, some mechanism will be necessary to review new information that may become available relative to lynx residency and/or reproduction that might indicate a need for a change or addition in an area's tier assignment. The Western Lynx Biology Team expects to have an ongoing role in evaluating new information and potential management implications.

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APPENDIX A - UTAH AND THE BIGHORN MOUNTAINS

The Forest Service currently manages for lynx in Utah on the Ashley and Uinta-Wasatch-Cache National Forests and participates in ESA consultation with the USFWS on projects that could potentially affect lynx habitat. The Bighorn National Forest's Forest Plan also requires management for lynx, although the USFWS no longer requires ESA consultation for this area. Both the Ashley and Bighorn National Forests are listed as 'peripheral' habitat under the NRLMD and are considered unoccupied and not actively managed under the NRLMD direction until and unless they are confirmed occupied by lynx.

Utah and the Bighorn Mountains in Wyoming are outside of the study area for both the Northern and Southern Rockies species distribution models developed by Olson et al. (2021) and Squires et al. (*in prep*). Therefore, the models were extrapolated to cover these areas using the same covariates from the same sources as in the published models. There is no telemetry data from resident lynx available from Utah or the Bighorns for model training or validation. Without validation data, it can't be determined with certainty if a model is accurately predicting lynx habitat or to discriminate among competing models (Olson and Squires, 2021 *pers. comm.*). Also, it is assumed that the relationship between lynx and their environment is the same in all locations as it is in the study area for which there is data, which may not be true as there will be differences in resource availability, competition, and population density, for example. (Yates et al. 2018, Buskirk et al. 2000).

From the analysis done by Olson and Squires (2021 *pers comm*.), predictions for Utah and the Bighorns from the Northern and Southern regional models appeared reasonable, with areas of relatively high probability habitat in generally forested, mountainous areas. The predictions often differed between the two models, however, with some areas predicted to be high probability habitat according to one model and less or low probability according to the other. Since no validation data exist for these areas, discriminating between these two models requires a subjective decision. Based on existing knowledge of the habitat and historical presence of lynx, particularly in the areas of northern Utah and the Greater Yellowstone Area, the Northern Regional model provides more reliable predictions for these areas than the Southern model. Therefore, the Team delineated conservation areas in Utah and the Bighorn Mountains based on the areas identified as high-quality habitat by the Northern Regional model (Figures A1 and A2).

Figure A1. Spatial Predictions of Canada lynx relative habitat probability in northern Utah.

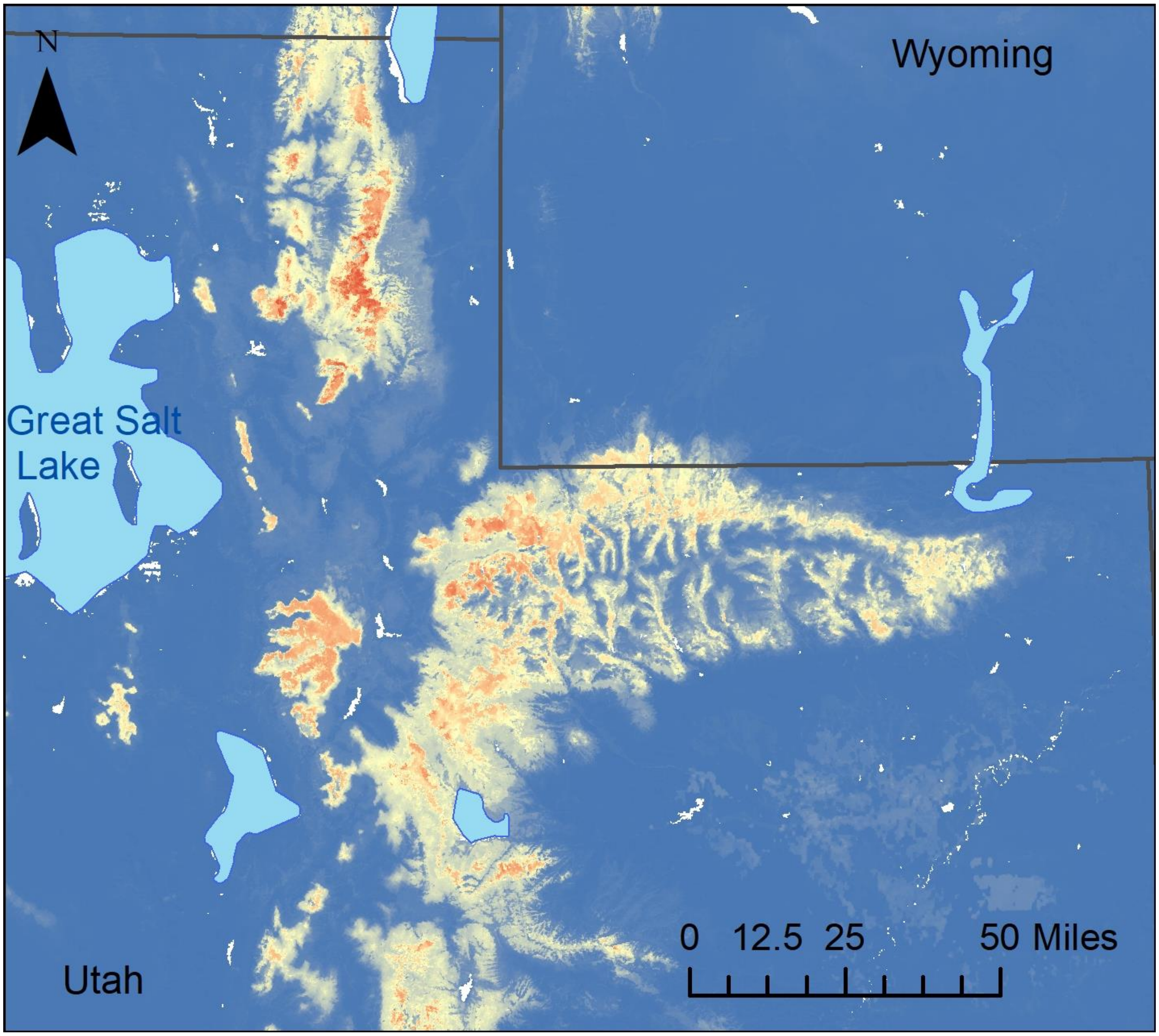
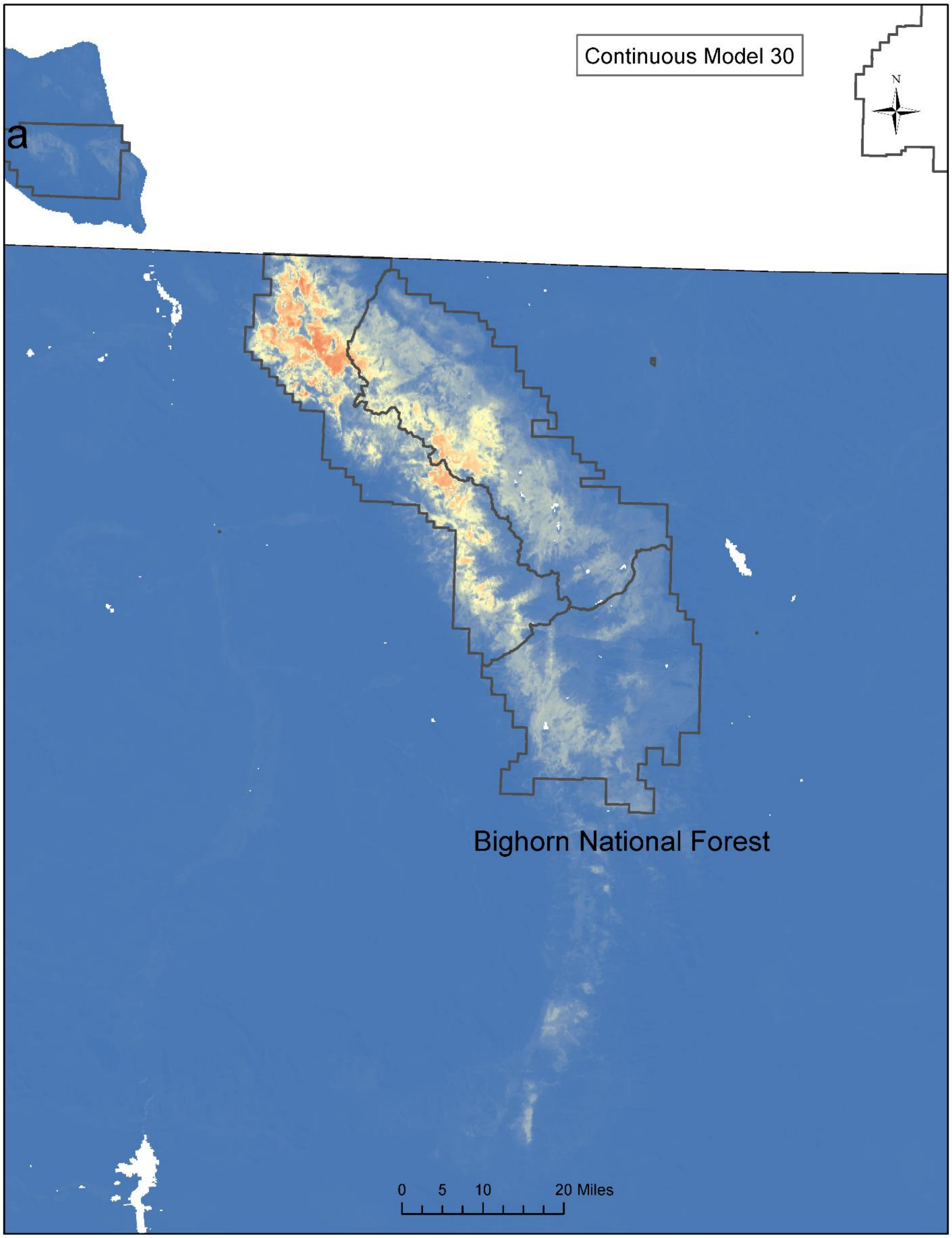


Figure A2. Spatial predictions of Canada lynx relative habitat probability in Bighorn Mtns, Wyoming.



APPENDIX B - SUMMARY OF OLSON ET AL. (2021)

This summary shares some of the methods and results from the Olson et al. (2021) publication to provide some foundational understanding of the model that became the basis for our remapping of Canada lynx habitat in the western U.S.

The authors developed a species distribution model (SDM) for the Canada lynx based on the best empirical data of lynx locations across the western U.S. landscape. These models are designed to quantify habitat distribution and quality based on environmental/habitat attributes at known sites selected by these animals and important to the species. A strength of Olson et al's (2021) SDM was the expansive dataset that was consolidated and used in the modeling, including testing the model with extensive independent data that collectively represented almost all known lynx detections across the Pacific Northwest study area.

The Olson et al. (2021) model extracted abiotic (non-vegetation) and biotic (vegetation) attributes at known locations that lynx selected and compared these to a random sample of background locations to predict a relative probability of lynx presence. The model was used to generate spatial predictions across the entire area in which background samples were drawn, including areas of similar environmental characteristics but where presence/absence of lynx is unknown, to produce a continuous surface map of lynx habitat potential (low > moderate > high) across the broad study area. Due to the large geographic area and variability in sample sizes, they also tested model performance and transferability among three data regions/lynx population areas in Washington, Montana, and Wyoming. The authors also tested the model for GPS "data efficiency," or the point at which additional data did not substantially improve model performance in predicting habitat.

(1) Study Area

The study area encompassed a broad geographic landscape that included parts of Washington, Idaho, Montana, Wyoming, British Columbia, and Alberta. This included location data from 3 monitored lynx populations in north-central Washington into Canada, western Montana, and northwest Wyoming. These were discrete populations in which lynx within them did not exhibit any observed east-west dispersal movements between the populations based on the telemetry locations of marked individuals.

(2) Occurrence Data

Occurrence data came primarily from GPS-collared individuals, although some Argos satellite data was also utilized to supplement smaller sample sizes in Wyoming. More specifically, the location data samples were 1) Washington = over 21,000 locations from 17 marked individuals monitored from 2007 to 2013; 2) Montana = over 164,000 locations from 66 individuals monitored from 2004 to 2015; and 3) Wyoming = 539 GPS locations and 218 Argos locations for 10 individuals from 1996 to 2010.

(3) Environmental Predictors

The authors initially selected environmental predictors based on known lynx natural history and ecological relationships. They eventually tested 16 climate, topographic, anthropogenic, and vegetation covariates for predicting lynx habitat across the regional surface. The authors provide more specifics about these covariates in their publication. To explore regional variation in model results between populations, they performed a principal components analysis using all 16 covariates and running the PCA on lynx locations from the same dataset used in the SDM modeling process.

(4) Model Development

The authors initially did not know whether a model constructed from all the data or from each lynx population (MT, WA, and WY) separately would provide the most predictive models of lynx presence/habitat. Therefore, they constructed SDMs for each of the 3 populations and a regional SDM of the combined populations. They split their combined regional study area into population areas, based on landscape features expected to be difficult for lynx to cross, such as large rivers and non-forested spaces. They selected six modeling algorithms in order to apply a range of regression (Boosted Regression Trees, Multiple Adaptive Regression Splines, Generalized Linear Models, and Generalized Additive Models) and machine learning methods (Random Forest, Maxent) commonly used in SDMs. They then created a final ensemble model by combining the predictions of these six algorithms using a weighted average, so that models that had more predictive accuracy were weighted more heavily in the ensemble.

(5) Model Validation

The authors used two datasets for SDM validation: a withheld set of GPS data not used in the model calibration and an extensive independent data set from a variety of sources that collectively represented most of the known independent lynx data sources available in the western U.S. These are further discussed in Section 5.2 of this paper.

The authors selected model thresholds based on a given percentage of lynx validation locations that fell above a given relative probability value on the continuous model surface (see Holbrook et al. 2017 and Olson et al. 2021 for a more detailed explanation). In the Olson et al. (2021) publication, several thresholds of varying levels were considered, depending on the desired conservation outcomes; the middle of this range of thresholds was 90% of lynx withheld GPS locations (deemed "high" probability use/habitat quality in the publication) and 85% of independent lynx locations ("moderate" probability of use/habitat quality). They assessed model performance for each SDM within the population on which it was calibrated, the three geographically separate populations to determine model transferability between regions, and across the regional surface with combined populations. For the best-performing predictive model, the authors also evaluated relative contribution of each covariate to better understand which environmental factors were contributing to modeled lynx distribution.

(6) Final Model Results

The lynx habitat map generated from the best-performing (most predictive) regional model was presented earlier in the main body of this paper (Fig. 2). Individual lynx population models performed well in their area but were less predictive when applied to a different population area or generalized across the study area, suggesting some variation in local habitat selection despite the known narrow habitat needs of Canada lynx.

However, the regional model built using data from the combined populations performed strongly across the entire study area. Their best performing SDM predicted areas favorable to lynx that were consistent with known lynx habitat use, with Canada lynx patchily distributed in mountainous areas in the Pacific Northwest and Greater Yellowstone Area. Applying 90% and 85% thresholds delineated habitat locations most likely to be selected by lynx in a reproductive population ("high" probability habitat) and habitat that was less favorable but potentially still used by lynx ("moderate" probability habitat), such as connectivity of habitat, or as part of a regional matrix of high and moderate probability habitat. The covariates having the most effect on lynx habitat probability in the regional model were related to temperature, moisture, and vegetation (snow, precipitation, cold temperatures, and NDVI as a measure of long-term forest presence or productivity).

APPENDIX C – FEDERAL LYNX HABITAT MANAGEMENT DIRECTION IN THE WEST

Existing lynx management direction and procedures for Federal agencies in the west will continue to apply, until that direction is modified as needed to better align with the key new science reflected in our revised lynx habitat map and new conservation recommendations. In general, Federal land management agencies in the Western U.S. either operate under lynx-specific direction and/or incorporate the Lynx Conservation Assessment and Strategy into their management actions.

We expect that some of the existing direction will need to be changed and/or supplemented given the substantial nature of the new science. To better understand the extent and character of any potentially needed changes (removal, modification, addition), we anticipate a process involving several iterative steps for our team: 1) review and update of the current Lynx Conservation Assessment & Strategy (LCAS 2013) with the new information; 2) evaluate the existing management direction against the updated LCAS to identify areas of disagreement; 3) propose areas of change needed to the existing management direction to better align with the updated LCAS; and 4) take appropriate steps to plan for changes under requirements of our agency laws, regulations, and policies.

Overview of Forest Service lynx management direction

- National Forests in the Northern Rockies are either operating under the Northern Rockies Lynx Management Direction (NRLMD) that was amended to their Forest Plans in 2007, or they have revised Forest Plans that incorporate the standards, guidelines, and objectives from the NRLMD.
- National Forests in Colorado and the Medicine Bow NF in southern WY are all operating under the Southern Rockies Lynx Amendment (SRLA), which amended Forest Plans in 2008.
- Forests currently map lynx habitat based on best available information, using guidance from the NRLMD, to provide general definitions[1] or, in the case of the SRLA, interagency implementation guidance.
- The Colville NF in Washington incorporated many of the lynx conservation measured from the LCAS into management direction standards and guidelines when their Forest Plan was recently revised. The Okanogan-Wenatchee NF in Washington has little management direction in its Forest Plan but uses the LCAS conservation measures to guide planned actions in lynx habitat and to evaluate effects to lynx.

Where NRLMD and SRLA are applied: NRLMD is required in “occupied lynx habitat,” as defined by the 2006 LCAS. (an area is considered occupied when: (1) there are at least two verified lynx observations or records since 1999 on the national forest, unless they are verified to be transient individuals; or (2) there is evidence of reproduction on the national forest. The direction should be “considered” for unoccupied units, but is not mandatory. However, the direction has been applied for several years on unoccupied units in Region 1, per FS Regional Forester letter. Unoccupied areas include all or parts of the Nez Perce-Clearwater, Salmon-Challis, Beaverhead-Deerlodge, Bitterroot, Ashley, and Bighorn NFs, and the disjunct mountain ranges on the Custer-Gallatin, and Helena-Lewis and Clark NFs.

SRLA is applied to all National Forests in CO and the Medicine Bow-Route in WY, as all are considered "occupied."

NRLMD and SRLA Standards (must be followed):

- New or expanded permanent developments and vegetation management projects must maintain habitat connectivity *in an LAU and/or linkage area;*
- If more than 30% of the lynx habitat in an LAU is currently in a stand initiation structural stage that does not yet provide winter snowshoe hare habitat, no additional habitat may be regenerated by vegetation management projects;
- Timber management projects shall not regenerate more than 15% of lynx habitat on NFS lands within an LAU in a ten-year period;
- Precommercial thinning projects that reduce snowshoe hare habitat are prohibited in lynx habitat from the stand initiation structural stage until the stands no longer provide winter snowshoe hare habitat only;
- Vegetation management projects that reduce snowshoe hare habitat in multi-story mature or late successional forests are prohibited.

Exemptions to standards allow fuel treatment projects within the Wildland Urban Interface (WUI).

Exceptions to standards allow few other circumstances (e.g. experimental thinning for research, around whitebark pine or aspen, around administrative sites, etc.).

These exceptions and exemptions shall occur on no more than roughly:

- 6% of lynx habitat on each Forest (under NRLMD);
- 3% of lynx habitat on each Forest for WUI exemptions, and 1.5% per LAU for exceptions (under SRLA).

Changes in LAU boundaries shall be based on site-specific habitat information and after review by the Forest Service Regional Office.

NRLMD and SRLA Guidelines (must be considered) related to:

- Lynx denning habitat
- Prescribed fire
- Fuel treatments in WUI
- Habitat for alternate prey

- Lynx habitat improvement
- Highways and overpasses
- Livestock grazing
- Human Use Projects
    - ski area expansion & development
    - mineral & energy development
    - road upgrading, brushing, locations
    - snow compaction
    - winter access for non-recreational special uses

Overview of Bureau of Land Management (BLM) lynx management direction

The BLM manages 1,424 km^2 (549 mi^2), or just over 1 percent, of the lands within the six geographic units evaluated in the lynx SSA (U.S. Fish and Wildlife Service, 2017). Over half of those lands are actively managed to support lynx conservation and nearly all occur in Colorado, Montana, and Wyoming.

In western Colorado (Critical Habitat Unit 6), 10 BLM Field Offices contain about 765 km^2 (295 mi^2) of potential lynx habitat. BLM resource management plans (RMPs) have been revised to include lynx conservation measures for 5 of the 10 Field Offices (Colorado River Valley, Grand Junction, Kremmling, Little Snake, and Tres Rios). Plan revisions are currently underway for 2 others (Royal Gorge and Uncompahgre). RMPs for the Gunnison, San Luis Valley, and White River Field Offices have not been revised and do not contain specific measures for the conservation of lynx; however, these areas constitute a very small proportion (2.3 percent) of potential lynx habitat in Colorado.

In western Montana (Unit 3), BLM lands in the Garnet Resource Area include 405 km^2 (156 mi^2) of designated lynx critical habitat that are managed in accordance with the 2021 Missoula Field Office Resource Management Plan. In western Wyoming (Unit 5), 261 km^2 (101 mi^2) of BLM lands on the Kemmerer and Pinedale districts are also designated as lynx critical habitat. The RMPs for these two districts were revised in 2008 and 2010, respectively, to adopt conservation measures and Best Management Practices (BMPs) for lynx.

APPENDIX D - SUMMARY OF PEER REVIEWER COMMENTS

In August 2022, five scientists with expertise in lynx ecology in the western U.S. were solicited to review the draft ***Spatial Framework for the Conservation of Canada Lynx Habitat in the Western U.S. and Associated Management Tiers*** (developed by the multi-agency Western Lynx Biology Team), for scientific soundness and defensibility. The review panel was selected by the WLBT's science advisor, Dr. John Squires, and included:

- Nick DeCesare (PhD), Research Biologist, Montana Fish, Wildlife & Parks.
- William Gaines (PhD), Research Wildlife Ecologist, Washington Conservation Science Institute.
- Joe Holbrook (PhD), Assistant Professor (Carnivore and Habitat Ecology), University of Wyoming.
- Jake Ivan (PhD), Wildlife Research Biologist, Colorado Parks and Wildlife.
- Benjamin Maletzke (PhD), Statewide Wolf Biologist, Washington Department of Fish and Wildlife.

The WLBT, with the aid of Dr. Squires, provided review panel members with seven questions to help focus the review. The questions were:

1) Does the refined spatial remapping of lynx habitat coupled with a tiered approach that provides desired forest mosaics represent a defensible conservation framework across the western U.S. when also combined with existing Lynx Conservation Measures (LCAS)?

2) Thus, in your judgment, is the revised framework scientifically defensible in suggesting a reduction of approximately 10 million acres in the Northern Rockies and 3 million acres in the Southern Rockies in habitat managed as important to Canada lynx?

3) Does the revised spatial framework help ensure that conservation/management efforts for Canada lynx in the western U.S. are primarily focused in the areas that are most naturally capable of supporting lynx?

4) The vegetation structural mosaic in Tier 1 reflects conditions in home ranges of female lynx successful at producing litters, while those in Tier 2 reflect the range of conditions within the home ranges of male and female lynx. The suggested approach for vegetation management in Tiers 1 and 2 is similar, with the primary difference being that LAUs in Tier 1 would be managed to contain 50-60% mature forest, while Tier 2 would be managed to contain no less than 50% mature forest. Both tiers may provide redundancy, resiliency, and representation of habitat across the range of lynx in the western U.S., but by managing for the conditions most conducive to females successfully reproducing, Tier 1 areas emphasize the value of areas that are modeled to have the highest proportion of

high-quality habitat. Do you think this suggested approach of managing vegetation differently in Tier 1 as compared to Tier 2 is sound?

5) Tier 3 polygons were identified with an objective of maintaining connectivity and facilitating dispersal of lynx across the landscape and among tiers, by providing habitat that could support periodic use by lynx during dispersal, and perhaps temporary occupancy. The Tier 3 vegetation structural mosaics reflect habitat conditions that provide for high quality foraging opportunities and shelter. Does this approach support dispersal and provide connectivity across the landscape for lynx, given their demonstrated ability to disperse long distances? Are there other potential Tier 3 areas we missed that you believe would have meaningful conservation value to dispersing lynx in the western U.S.?

6) Does this revised spatial and management-tier framework provide adequate considerations for the future of lynx conservation in the western U.S. in the face of a changing climate?

7) Overall, did the WLBT provide a sufficient description in this document regarding the process used to adapt and refine the Olson et al (2021) modeled map of relative habitat suitability to the Team's primary objective of identifying discrete areas of highest value and priority for conservation of Canada lynx across the western U.S. landscape? Which sections might have been improved or clarified to help your review?

A summary of the responses is provided below, with an attempt to highlight substantive support, concerns, and recommendations. Because many of the responders weaved a prominent theme throughout their responses, the summary is arranged more thematically than by direct order of the questions.

<u>Support</u>

The team appropriately used Olson et al. (2021) and Squires et al. (*in prep*) models as the basis for their refined mapping.

Areas identified in the refined mapping closely align with areas of contemporary occupancy by lynx, as well as other areas that may be important to lynx.

The Framework appropriately focuses conservation in areas naturally capable of supporting lynx. This provides a justifiable basis for reducing the conservation footprint relative to the current footprint.

<u>Concerns</u>

The Framework is based on contemporary vegetation and landscape patterns (i.e., abundant mature forest), which have resulted from decades of fire suppression. However, these patterns may not reflect historic, future, or sustainable conditions. In particular, there is concern that for some areas aiming for 50-60% mature forest is not sustainable currently or in the future.

Concern that the Framework is not responsive to climate change (e.g., changes in fire and snow), which is the main pressure influencing lynx habitat. Habitat will move, shift, or become reduced as large fires increase on the landscape and snow patterns change; however, the areas delineated for focused lynx conservation are fixed to where high-quality habitat currently exists.

The Framework is based on lynx habitat use obtained in the western U.S. in modern times (i.e., through data obtained from lynx that were telemetered in a subset of Tier 1 areas). There is lack of data on how lynx might use areas identified as Tier 2 or Tier 3. The utility of Tier 3 areas may be limited because lynx do not require mature forest to disperse.

The desired tier vegetation mosaics may be challenging to measure and attain. For example, there is little difference between Tier 1 and Tier 2 mosaics. Also, a meaningful way to measure mature forest connectivity does not currently exist and may be constrained by logistical or financial considerations.

The Framework does not explicitly emphasize prey, and therefore may not respond to non-vegetation environmental drivers that could de-couple the climate-lynx model.

Recommendations

Conservation recommendations should consider and respond adaptively to patterns of snow, increasing severe fire, and other changing conditions.

Consider ways to re-pattern the landscape with a mix of structure types to create more area with low fuels and less area with high fuels.

Address the role of fire and other disturbances, including positive effects.

Include future projections of lynx habitat, which might need a new threshold or new tier.

Clarify what is meant by ‘historical’ occupancy and use areas, given the reliance on modern data obtained through telemetry studies conducted in contemporary landscapes.

Clarify the differentiation of functional tiers and their respective importance to lynx conservation.

Clarify how tier polygons were selected, including more details on ‘patch tool’ mechanics and judgment used to exclude some areas.

Consider merging Tier 1 and Tier 2 areas, and/or address whether Tier 2 areas could be managed to become Tier 1 habitats.

Consider the utility and placement of Tier 3 habitats as effective ‘stepping stones,’ in part by determining vegetation conditions that occurred along known dispersal paths. Consider adding the Snowy Range (WY) as a Tier 3 area based on previous use.

Define connectivity in a meaningful, efficient way that can be measured by forest managers.

Show how the Framework ensures, or assumes, that suitable prey will be found in the tiers.