

Species Status Assessment

for the

CANADA LYNX (*Lynx canadensis*)

Contiguous United States Distinct Population Segment



Photo by Keith Williams

Version 1.0 - Final
October 2017

U.S. Fish and Wildlife Service
Regions 1, 3, 5 and 6

Recommended Citation

U.S. Fish and Wildlife Service. 2017. Species Status Assessment for the Canada lynx (*Lynx canadensis*) Contiguous United States Distinct Population Segment. Version 1.0, October, 2017. Lakewood, Colorado.

Credits

This SSA report was produced by the Canada Lynx Species Status Assessment Team (Lynx SSA Team), which consists of a Core Team of Service biologists who work on lynx conservation across the DPS range and an SSA Framework Implementation Team of Service and U.S. Geological Survey staff who have developed and advanced the SSA framework.

U.S. Fish and Wildlife Service Lynx SSA Core Team

Jim Zelenak (Lead), Region 6, Montana Ecological Services Field Office: Chapters/sections - Executive Summary, 1, 2, 3.1, 3.4, 6, and Units 3 and 5
Mark McCollough (Co-lead), Region 5, Maine Ecological Services Field Office: Sections - 3.2, 3.3, 3.5, and Unit 1
Kurt Broderdorp, Region 6, Western Colorado Ecological Services Field Office: Unit 6
Bryon Holt, Region 1, Northern Idaho Ecological Services Field Office: Unit 4
Tamara Smith, Region 3, Minnesota-Wisconsin Ecological Services Field Office: Unit 2

All Core Team members participated in development of conceptual models and reviewed and provided comments/edits on other sections of the SSA report. All members also helped identify and contact lynx expert panelist candidates and other subject matter experts and contributed to expert elicitation and the report of the Expert Elicitation Workshop (see Acknowledgments).

SSA Framework Implementation Team

Heather Bell, USFWS Headquarters, Ecological Services, Division of Restoration and Recovery
Mary Parkin, USFWS Region 5, Endangered Species Recovery Coordinator
Justin Shoemaker, USFWS Region 6, Classification and Recovery Biologist
Jonathan Cummings, USGS - Patuxent Wildlife Research Center, Research Ecologist

The Framework Implementation Team (FIT) developed and facilitated the expert elicitation process. J. Cummings compiled, analyzed, graphed, and summarized the information generated via expert elicitation and created, with Core and FIT input, conceptual models presented in section 1.3. All FIT members contributed to the Executive Summary and sections 1.2 and 1.3, and all provided technical review and editing of other parts of the report.

Administrative and Technical Support: Marigaye Bissell, Barbara Chavez, Kaimy Marks, and Karen Newlon, Montana Ecological Services Field Office.

Acknowledgments

This report relies heavily on the input and professional opinions provided by a panel of 10 recognized lynx experts and captured during a formal Expert Elicitation Workshop held in Bloomington, Minnesota, October 13-15, 2015. Several other recognized lynx experts from Canada and the contiguous United States were invited but unable to participate. The workshop also was supported by and benefitted from the participation and presentations of other recognized experts in the fields of snowshoe hare ecology, lynx genetics, forest ecology, climate change modeling, and Federal lynx habitat management.

Canada Lynx Expert Panel Members (alphabetically)

Jeff Bowman, Ontario Ministry of Natural Resources and Forestry, University of Trent, Ontario
Susan Catton, USDA Forest Service - Superior National Forest, Duluth, MN
Jake Ivan, Colorado Parks and Wildlife, Department of Natural Resources, Fort Collins, CO
Jay Kolbe, Montana Department of Fish, Wildlife and Parks, White Sulphur Springs, MT
Benjamin Maletzke, Washington Department of Fish and Wildlife, Olympia, WA
Kevin McKelvey, USDA Forest Service - Rocky Mountain Research Station, Missoula, MT
Ron Moen, University of Minnesota, Natural Resources Research Institute, Duluth, MN
Erin Simons-Legaard, University of Maine, School of Forest Resources, Orono, ME
John Squires, USDA Forest Service - Rocky Mountain Research Station, Missoula, MT
Jennifer Vashon, Maine Department of Inland Fisheries and Wildlife, Bangor, ME

Canada Lynx Expert Elicitation Workshop Presenters (alphabetically)

Lee Frelich, University of Minnesota Center for Forest Ecology, St. Paul, MN
Karen Hodges, University of British Columbia–Okanagan, Kelowna, BC Canada
Scott Jackson, USDA Forest Service - National Carnivore Program Leader, Missoula, MT
Josh Lawler, University of Washington School of Environmental & Forest Sciences, Seattle, WA
Michael Schwartz, USDA Forest Service - National Genomics Center for Wildlife & Fish Conservation, Missoula, MT
Alexej Siren, DOI Northeast Climate Science Center, University of Massachusetts, Amherst, MA
Chad Wilsey, National Audubon Society, San Francisco, CA

The Canada Lynx Expert Elicitation Workshop Report can be found here:

<https://www.fws.gov/mountain-prairie/es/species/mammals/lynx/SSA2016/Appendices/2016%2004%2018%20FINAL%20Lynx%20SSA%20EE%20Workshop%20Report%20%20jzeds.pdf>

Report appendices, expert presentations, and other supporting materials can be found under the “Species Status Assessment (SSA)” tab at:

<https://www.fws.gov/mountain-prairie/es/canadaLynx.php>

This report also relies heavily on the Interagency Lynx Biology Team's *Canada Lynx Conservation Assessment and Strategy*, 3rd Edition, August 2013:

Interagency Lynx Biology Team. 2013. Canada lynx conservation assessment and strategy. 3rd edition. USDA Forest Service, USDI Fish and Wildlife Service, USDI Bureau of Land Management, and USDI National Park Service. Forest Service Publication R1-13-19, Missoula, MT. 128 pp.
http://www.fs.fed.us/biology/resources/pubs/wildlife/LCAS_revisedAugust2013.pdf.

All Lynx SSA Core Team members participated in development and review of the revised LCAS.

Table of Contents

Credits	i
Acknowledgments.....	ii
Table of Contents.....	iv
Executive Summary	1
Chapter 1: Introduction.....	11
1.1 Background	11
1.2 SSA Framework and Report.....	14
1.3 Analytical Approach and Methods	16
1.4 Uncertainties and Assumptions	21
Chapter 2: Lynx Ecology	23
2.1 Species Taxonomy, Description, and Genetics.....	23
2.2 Life History and Population Dynamics	26
2.2.1 Ecological Requirements of Individuals	32
2.2.2 Ecological Requirements of Populations and the DPS	36
2.3 Historical and Current Lynx Distribution.....	38
2.3.1 Lynx Distribution and Status in Canada and Alaska	38
2.3.2 Lynx Distribution in the Contiguous United States	39
2.3.2.1 Defining Lynx Distribution at the Periphery of the Range	39
2.3.2.2 Lynx Distribution within the DPS Range.....	42
Chapter 3: Factors Influencing Viability of the DPS.....	51
3.1 Regulatory Mechanisms	52
3.1.1 Federal Regulatory Mechanisms.....	52
3.1.2 State Regulations and Tribal Management.....	58
3.2 Climate Change.....	66
3.3 Vegetation Management.....	83
3.4 Wildland Fire Management.....	92
3.5 Habitat Loss and Fragmentation.....	96
Chapter 4: Current Conditions.....	105
4.1 Summary of Current Conditions DPS-wide	106
4.1.1 Summaries of Current Conditions in Each Geographic Unit	108
4.2 Current Conditions - Detailed Descriptions by Geographic Unit	113

4.2.1 Unit 1 - Northern Maine	113
4.2.2 Unit 2 - Northeastern Minnesota.....	128
4.2.3 Unit 3 - Northwestern Montana/Northeastern Idaho	133
4.2.4 Unit 4 - North-central Washington	147
4.2.5 Unit 5 - Greater Yellowstone Area.....	153
4.2.6 Unit 6 - Western Colorado.....	161
Chapter 5: Future Conditions	166
5.1 Summary of Future Conditions DPS-wide.....	169
5.1.1 Summaries of Future Conditions in Each Geographic Unit.....	173
5.2 Future Conditions - Detailed Descriptions by Geographic Unit.....	180
5.2.1 Unit 1 - Northern Maine	180
5.2.2 Unit 2 - Northeastern Minnesota.....	195
5.2.3 Unit 3 - Northwestern Montana/Northeastern Idaho	204
5.2.4 Unit 4 - North-central Washington	212
5.2.5 Unit 5 - Greater Yellowstone Area.....	217
5.2.6 Unit 6 - Western Colorado.....	223
Chapter 6: Synthesis.....	228
Literature Cited	238

FIGURES

Figure 1. Six geographic units within the range of the contiguous United States distinct population segment of Canada lynx (<i>Lynx canadensis</i>).....	2
--	---

Figure 2. Cumulative probabilities that resident lynx populations will persist in at least a given number of geographic units over time (at years 2015 [current at time of expert elicitation], 2025, 2050, and 2100) based on experts’ predictions for individual geographic units. Experts’ “most likely” probabilities are summarized in the middle column; their highest (“better case”) and lowest (“worse case”) probabilities, representing uncertainty in their predictions, are summarized in the left and right columns, respectively. See section 5.1 for additional details on graph construction and interpretation.	6
--	---

Figure 3. SSA Framework stages.....	15
-------------------------------------	----

Figure 4. Conceptual model of the factors thought to influence the 3 Rs as they pertain to lynx viability.....	16
--	----

Figure 5. Conceptual model of factors thought to influence redundancy within the lynx DPS. ...	17
--	----

Figure 6. Conceptual model of factors thought to influence representation within the lynx DPS.18

Figure 7. Conceptual model of factors thought to influence the resiliency of lynx populations within the DPS.19

Figure 8. Generalized relationship between habitat conditions and hare and lynx population dynamics and their influence on lynx population resiliency.....26

Figure 9. Summary of lynx experts’ predictions regarding the probability of persistence of at least a given number of geographic units given the probability of persistence for each individual geographic unit. The y axis of each grid in figure 9 is the probability that at least the number of geographic units indicated by the x axis of the grid persist. The probability in a bar reaches 1 when there is no probability of fewer geographic units persisting. Moving from top to bottom, the grids show the probabilities by time period (2015 [current at time of expert elicitation], 2025, 2050, and 2100). Moving from left to right the grids show the range of expert responses by summary selection type and probability response. Therefore, looking down a column of grids provides a view of the trend in persistence through time and looking across a row of grids provides a view of the range of uncertainty in expert projections of persistence for a given time period.....170

Figure 10. Lynx expert estimates of the probability that the Northern Maine Geographic Unit will continue to support resident lynx in the future (at years 2025, 2050, and 2100).182

Figure 11. Lynx expert estimates of the probability that the Northeastern Minnesota Geographic Unit will continue to support resident lynx in the future (at years 2025, 2050, and 2100).....196

Figure 12. Lynx expert estimates of the probability that the Northwestern Montana/Northeastern Idaho Geographic Unit will continue to support resident lynx in the future (at years 2025, 2050, and 2100).....206

Figure 13. Lynx expert estimates of the probability that the North-central Washington Geographic Unit will continue to support resident lynx in the future (at years 2025, 2050, and 2100).214

Figure 14. Lynx expert estimates of the probability that the Greater Yellowstone Area Geographic Unit will continue to support resident lynx in the future (at years 2025, 2050, and 2100).218

Figure 15. Expected probability of persistence for the Western Colorado Geographic Unit at present, 2015, and in 2025, 2050 and 2100.224

TABLES

Table 1. Summary of expert opinion regarding the likelihood that individual geographic units will continue to support resident lynx populations in the future¹..... 5

Table 2. Lynx SSA Unit Sizes and Percent Ownership.....14

Table 3. Reported annual home range sizes for Canada lynx in the contiguous United States. 34

Table 4. Summary of current conditions in 6 geographic units within the DPS range¹.....113

Table 5. Expert-predicted future (2025, 2050, and 2100) persistence¹ of resident lynx populations in individual geographic units of the Canada lynx DPS and supporting evidence and uncertainties.178

Executive Summary

This report presents the results of a species status assessment (SSA) for the contiguous United States distinct population segment (DPS) of Canada lynx (*Lynx canadensis*). The report represents the U.S. Fish and Wildlife Service's (Service's) evaluation of the best available scientific information, including the formally elicited professional judgments and opinions of recognized lynx experts. Based on this information, we (1) describe the ecological requirements and population dynamics of the species; (2) evaluate the historical and current condition of lynx populations in the DPS and the factors that appear to have influenced them; and (3) assess the DPS's near-term (at year 2025), mid-term (year 2050), and longer-term (year 2100) viability. This final SSA has been revised in response to the reviews, comments, and suggestions of 5 independent peer reviewers, 11 State wildlife and natural resources management agencies, and 3 other Federal agencies.

Background

The Canada lynx is a North American boreal forest carnivore whose populations are strongly tied to its primary prey, the snowshoe hare (*Lepus americanus*). Both species occur primarily in the extensive boreal spruce-fir forests of Canada and Alaska; however, the southern margins of both their ranges extend into the northern contiguous United States. The Service designated lynx in the Lower 48 States as a DPS because of differences in the management of lynx and lynx habitats across the international boundary with Canada and because of the climatic, vegetative, and ecological differences between lynx habitat at the southern extent of its range in the contiguous United States compared to the northern range in Canada and Alaska. The Service listed the DPS as threatened under the Endangered Species Act (ESA) in 2000 because of the inadequacy, at that time, of regulatory mechanisms on some Federal lands to provide for the conservation of lynx habitats and populations (see section 3.1.1). This SSA does not reconsider the designation of the DPS or its listing status under the ESA, which are Service policy decisions. Instead, it provides the scientific basis for the statutorily required 5-year status review for the DPS and other decisions the Service is required to make in accordance with the ESA.

In this SSA, we evaluate the current and possible future conditions for lynx in 6 geographic units within the DPS range that currently support or recently supported resident lynx. The units are distributed from Maine to Washington and south along the Rocky Mountains to western Colorado (fig. 1). Units 1 (Northern Maine), 2 (Northeastern Minnesota), 3 (Northwestern Montana/Northeastern Idaho), and 4 (North-central Washington) historically supported and currently support resident lynx populations. Based on verified records, it is uncertain whether Units 5 (Greater Yellowstone Area [GYA]) and 6 (Western Colorado) historically supported persistent populations or if they supported resident lynx only ephemerally (see section 2.3.2.2). Combined, the 6 units encompass over 131,000 km² (about 50,640 mi²) of occupied or potential lynx habitat and represent roughly the southern 2 percent of the species' breeding distribution (98 percent occurs in Canada and Alaska). Land ownership varies among the units, with private

lands accounting for most of Unit 1; a mix of Federal, State and private lands in Unit 2; and predominantly Federal lands in the 4 western units (see table 2, chapter 1 for additional details on unit sizes and land ownership).

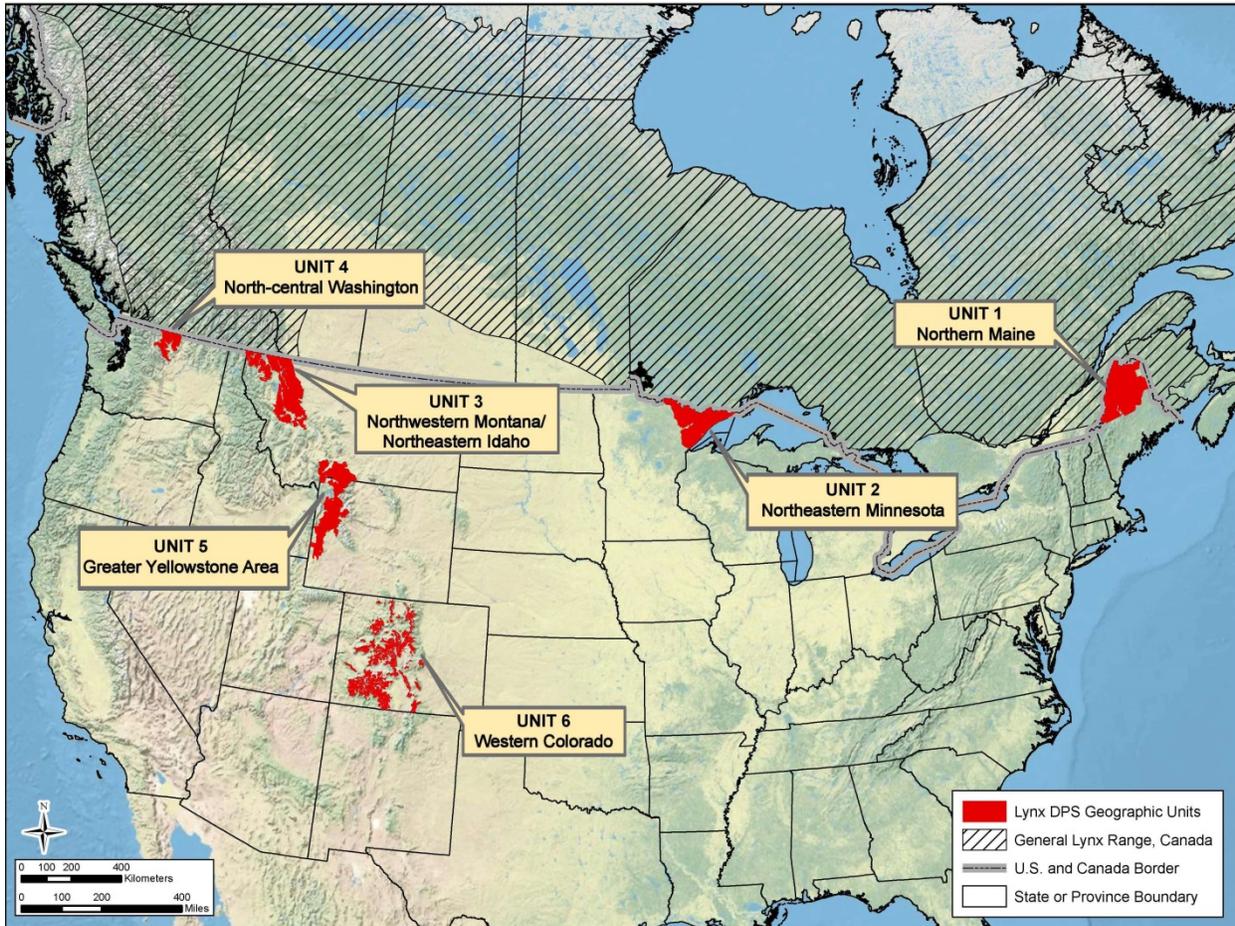


Figure 1. Six geographic units within the range of the contiguous United States distinct population segment of Canada lynx (*Lynx canadensis*).

The lynx is a habitat and prey specialist that requires dense boreal and subalpine forests that support abundant snowshoe hares, which typically constitute greater than 90 percent of the lynx’s year-round diet. Lynx and hares are most abundant in areas with long winters and persistent deep, powdery snow. The lynx has evolved morphological adaptations - long legs and exceptionally large paws - which in snowy conditions are thought to confer a competitive advantage over other terrestrial hare predators and allow lynx to occupy habitats that are unavailable, at least seasonally, to some of its potential competitors. The DPS occurs at the southern margin of the species’ range, where boreal forest habitats and thus lynx are, in most places, naturally less abundant and generally more patchily-distributed than in the core of the species’ range in Canada and Alaska. Maintaining connectivity between the DPS and lynx populations in Canada is thought to be important. However, the extent to which DPS populations may depend on immigration of lynx from Canada remains uncertain.

Our understanding of lynx biology has improved substantially since the DPS was proposed for listing in 1998. For example, analysis of historical trapping data indicated that many lynx records in the contiguous United States coincided with the intermittent (roughly decadal) mass dispersal (“irruptions”) of lynx from Canada into the northern United States when hare populations in Canada underwent steep cyclic declines. During these events, particularly the unprecedentedly large irruptions of the early 1960s and early 1970s, hundreds to thousands of lynx dispersed south into both suitable and unsuitable habitats in the northern United States. In suitable habitats, immigrants may have contributed to the demographic and genetic health of resident populations; in unsuitable habitats, dispersing lynx occurred only temporarily and disappeared relatively quickly from areas that are not capable of supporting resident populations over the long-term. Research and monitoring conducted by State, Federal, and Tribal agency partners and academic institutions also have refined our understanding of lynx habitat requirements and associations, distributions, demography, and potential stressors throughout the DPS range (see Summary of Findings, below, and chapters 2-4).

SSA Framework

The SSA framework considers a species’ life history and ecological requirements to understand how the species maintains itself over time. Therefore, we evaluated the ecological requirements of individual lynx and populations and the current and possible future conditions for resident lynx populations in each geographic unit to assess the viability of the DPS. The SSA uses the conservation biology principles of resiliency, redundancy, and representation (the “3 Rs”) as the framework for assessing current and future conditions. Resiliency describes the ability of populations and species to withstand stochastic events, redundancy describes a species’ ability to withstand catastrophic events, and representation describes a species’ ability to adapt to long-term changes in the environment (see sections 1.2 and 1.3). For lynx, the factors capable of influencing the 3 Rs that we evaluate in this SSA include the adequacy of existing regulatory mechanisms (the factor for which the DPS was listed); climate change, vegetation management, wildland fire management, and habitat loss and fragmentation (the factors considered by the Interagency Lynx Biology Team [ILBT] to have the potential to exert population-level effects on the DPS); and other factors that could influence the continued ability of particular geographic units to support resident lynx.

Uncertainties and Assumptions

Several sources of uncertainty had to be accounted for in our analysis, including limited data on lynx population sizes, trends, and other important demographic parameters in the DPS; the influence of lynx immigration from Canada on the persistence of the DPS; the effectiveness of habitat management efforts; and the potential effects of competition. We similarly lack consistent habitat and demographic information for snowshoe hares throughout much of the DPS range. Given the emerging role of climate change as a stressor, uncertainties about the timing, rate, and magnitude of projected future impacts to hares; boreal, subalpine, and montane forests; and snow quality, depth, and persistence constrain our ability to precisely predict effects on lynx populations and habitats. To account for these uncertainties in our

analysis, we identified a number of critical assumptions based on the scientific literature and input provided by the lynx experts we consulted (see section 1.4).

As part of our evaluation of the DPS's viability, we asked a panel of 10 lynx experts to provide their opinions on the likelihoods that each geographic unit would support resident lynx populations in the short-term (at year 2025), mid-term (at year 2050) and longer-term (at year 2100). The level of uncertainty regarding the viability of the DPS and each of the factors that may influence it increases the farther into the future we (and the experts we consulted) try to look, and this uncertainty greatly reduces confidence in projections, particularly beyond mid-century. The output from this expert elicitation process (summarized below and presented in detail in chapter 5) remains the experts' best professional judgment, and readers should consider the inherent limitations and substantial uncertainties in expert responses, particularly over longer time periods (see also section 1.4 and chapter 5).

Summary of Findings

Much irresolvable uncertainty remains regarding the historical distributions and sizes of resident lynx populations in the contiguous United States. Several small populations may have been extirpated from some areas within or adjacent or peripheral to the geographic units we assess and a recent fire-driven decline in lynx numbers in Unit 4 seems likely. However, we find no compelling evidence, based on verified historical records, of major range contraction or dramatic declines in the number of resident lynx in the DPS as a whole (see section 2.3.2). In fact, there are currently more resident lynx in some parts of the DPS (Maine and Colorado) than likely occurred historically and, in those areas and in Minnesota, there are more resident lynx now than was suspected when the DPS was listed. Further, some areas suspected to have lost historical lynx populations may have been (and perhaps are now) naturally capable of supporting resident lynx only ephemerally or intermittently, as would be expected in marginal habitats at the southern periphery of the species' range under a metapopulation structure like that thought to govern DPS lynx populations (see sections 2.2 and 4.1).

Lynx conservation measures and habitat management guidance adopted by the U.S. Forest Service (USFS) and the Bureau of Land Management (BLM) via formally amended or revised management plans or conservation agreements with the Service have substantially addressed the singular threat for which the DPS was listed (the inadequacy of regulatory mechanisms when the DPS was listed; see section 3.1). Conservation efforts by State, Tribal, and other Federal agencies; conservation organizations; and some private landowners also have secured protection of lynx habitats and reduced a number of other potential stressors to lynx populations and habitats throughout the DPS range. Nonetheless, we and the experts we consulted expect that resident population sizes and distributions in the DPS will likely decline largely as a result of projected continued climate warming and associated impacts, which are likely to exacerbate the potential adverse effects of other stressors.

Although the timing and extent of climate-mediated impacts are uncertain, continued warming is expected to cause a northward and upslope contraction of the boreal forest, snow conditions,

and hare populations that support lynx, along with several other potential impacts (see section 3.2). This, in turn, will likely result in smaller, more fragmented, and increasingly isolated patches of habitat and smaller, more isolated lynx populations in the DPS that would be more vulnerable to stochastic demographic and catastrophic events and genetic drift. It also may improve conditions for other terrestrial hare predators, potentially resulting in increased competition and displacement of lynx from areas that currently support resident populations. Climate-driven increases in the frequency, size, and intensity of wildfires and forest insect outbreaks are also expected to continue, although we do not anticipate that such events alone would cause the permanent loss of breeding lynx populations in any geographic unit. We are aware of no management actions that could be expected to abate the projected long-term retreat of boreal forests, declining hare populations, and diminished snow conditions expected under continued climate warming.

Despite the anticipated long-term effects of climate warming and the effects of other potential stressors (see chapter 3), we and the experts we consulted expect that each of the 5 geographic units that currently supports resident populations (Units 1-4 and 6) individually has a high likelihood (80 to 98 percent based on median “most likely” expert projections; see table 1, below, and section 5.2, figs. 10-13 and 15) of continuing to do so at year 2025. Experts similarly indicated high likelihoods (70 to 90 percent) that those units will continue to support resident populations through 2050, albeit in reduced numbers and distributions. Experts projected that only Unit 3 has a high (78 percent) likelihood of supporting resident lynx by 2100; all other geographic units individually were deemed to have a 50 percent or greater likelihood of functional extirpation (i.e., no longer capable of supporting resident lynx populations) by the end of the century; however, all experts expressed great uncertainty in their projections for that time period (see section 1.4 and the introduction to chapter 5).

Table 1. Summary of expert opinion regarding the likelihood that individual geographic units will continue to support resident lynx populations in the future¹.

Geographic Unit	Year					
	2025		2050		2100	
	Probability of Persistence (%) ²	Range (%) ³	Probability of Persistence (%)	Range (%)	Probability of Persistence (%)	Range (%)
1	96	80-100	80	65-95	50	40-80
2	96	88-100	80	60-90	35	10-60
3	98	95-100	90	70-100	78	50-90
4	80	60-95	70	30-80	38	5-50
5	52	10-70	35	15-60	15	5-50
6	90	60-100	80	50-85	50	20-70

¹We asked 10 recognized lynx experts to provide their estimates of the probability that resident lynx populations or subpopulations would persist in each geographic unit, even if reductions in lynx numbers and distributions were anticipated (i.e., the probability that resident lynx would *not* be functionally extirpated from the unit).

²Median “most likely” probabilities of persistence provided by 10 lynx experts for each geographic unit considering the current status of lynx populations and current and likely future stressors to those populations. Green = 68–100% median probability of persistence; Yellow = 34–67% median probability of persistence; Red = 0–33% median probability of persistence.

³The full range of “most likely” probabilities of persistence provided by the 10 lynx experts.

Cumulatively, expert median “most likely” responses suggest a high (80 percent) likelihood that resident lynx populations will persist in all 5 units that currently support them at year 2025 and in at least 4 of the 5 units at 2050, and a moderate (just under 50 percent) likelihood that they will persist in all 5 units at 2050 (fig. 2, middle column; also see section 5.1). Over the longer-term, expert responses suggest a high (about 85 percent) likelihood that resident populations will persist in at least 2 of the 5 units at 2100 and a more than 50 percent likelihood they will persist in 3 units, but also a high (> 75 percent) likelihood that resident populations will be functionally extirpated from 2 of the 5 units by the end of the century (fig. 2).

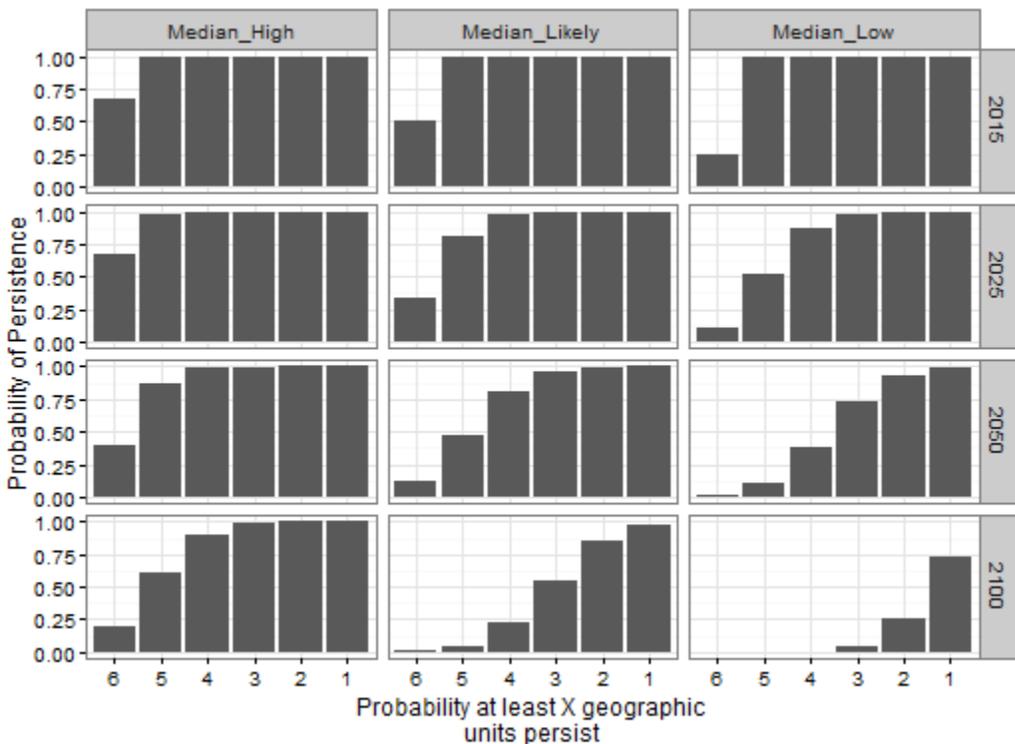


Figure 2. Cumulative probabilities that resident lynx populations will persist in at least a given number of geographic units over time (at years 2015 [current at time of expert elicitation], 2025, 2050, and 2100) based on experts’ predictions for individual geographic units. Experts’ “most likely” probabilities are summarized in the middle column; their highest (“better case”) and lowest (“worse case”) probabilities, representing uncertainty in their predictions, are summarized in the left and right columns, respectively. See section 5.1 for additional details on graph construction and interpretation.

Below we summarize lynx status in each geographic unit based on our understanding of conditions historically, at the time the DPS was listed, and currently, and considering expert opinions regarding potential population sizes and future persistence. See section 2.3.2 for a detailed assessment of historical and current lynx distribution across the DPS range and chapters 4 and 5, respectively, for detailed evaluations of current and possible future conditions in each geographic unit.

Unit 1 - Currently, northern Maine is thought to support many more resident lynx than likely occurred historically and many more than was known or suspected at the time the DPS was

listed, and recent information suggests that resident lynx may be expanding to the south of the core population area. This is due to the large amount and broad distribution of high-quality lynx and hare habitat that currently exists as a result of landscape-level clearcutting on private commercial timber lands in response to a major spruce budworm (*Choristoneura fumiferana*) outbreak in the 1970s and 1980s. These dense regenerating conifer stands are much more extensive than they are thought to have been historically under natural disturbance regimes. The State of Maine suggests that this unit currently may support 750-1,000 or more resident lynx. However, the extent of these high-quality stands probably peaked by 2010, and habitat quality is projected to decline in these stands over the next few decades as they age beyond 35-40 years post-harvest. Because a shift in forest management from clearcutting to partial harvesting that began in 1989 appears unlikely to maintain or recreate this extensive high-quality habitat, we expect lynx habitat and numbers to decline in this unit over the next several decades, perhaps to levels more consistent with likely historical conditions. We concur with the expert panel that the resident lynx population in this unit is very likely to persist at 2025 and at 2050. Over the longer-term (at 2100), we expect continued climate warming to reduce the amount and quality of lynx habitat in this unit and exacerbate other potential stressors (commercial and energy developments, changing forestry practices and land ownership patterns, etc.), further reducing lynx numbers and likely decreasing the population's resilience. Some climate models indicate substantial loss of boreal forest and favorable snow conditions under higher emissions scenarios, and this unit generally lacks potential elevational refugia that would support upslope movement of lynx habitats and populations. Therefore, we suggest that the likelihood that this unit will support a resident lynx population at 2100 may be somewhat lower than expert projections, although the timing and extent of climate-mediated habitat decline is highly uncertain. This geographic unit also may be the source of dispersing lynx that recently recolonized northern New Hampshire as well as several that temporarily established residency in northern Vermont. Some reproduction has been verified recently in both states, although neither was occupied when the DPS was listed, and resident lynx were thought to have been extirpated from New Hampshire.

Unit 2 - Northeastern Minnesota similarly supports many more resident lynx than was suspected when the DPS was listed (when it was unknown whether a resident population occurred there at all), although how the current population compares to historical conditions is uncertain. Trapping records indicate strongly cyclic increases in lynx abundance in this unit in the 1930s through 1970s in association with decadal irruptions of lynx dispersing south from Canada. Currently, Minnesota lynx experts suggest that the population in this unit likely fluctuates from 50 to 200 resident lynx, and we find no evidence that it historically supported a larger resident population or a more extensive distribution of habitat capable of doing so. We concur with the expert panel that the resident lynx population in this unit is very likely to persist at 2025 and at 2050. Over the longer-term (at 2100), we expect continued climate warming to reduce the amount and quality of lynx habitat in this unit, reducing lynx numbers and likely decreasing the population's resilience. Under higher emissions scenarios, some climate models project substantial loss of boreal forest and favorable snow conditions in this unit before the end of the century. Like Maine, this unit also lacks potential elevational refugia that would support upslope movement of lynx habitats and populations. Therefore, we suggest that the likelihood that resident lynx will persist in this

unit at 2100 may be somewhat lower than expert projections, although the timing and extent of climate-mediated habitat decline is highly uncertain.

Unit 3 - Recent research, monitoring, and habitat mapping refinements indicate that habitats capable of supporting resident lynx in this and other western geographic units are naturally less abundant and more patchily-distributed than was thought when the DPS was listed. For example, earlier estimates that western Montana supported 1,000 or more lynx were based on broad assumptions regarding habitat suitability and lynx distribution that are not supported by current understanding of lynx habitat requirements (see section 4.2.3). Currently, this unit is thought to be capable of supporting 200-300 resident lynx. How the current population compares to historical conditions is uncertain, but we find no evidence that this unit historically supported a larger resident population or a substantially broader distribution of habitat capable of doing so. Lynx habitats in this unit are naturally patchy and fragmented due to topography and elevational and moisture (aspect) constraints. We concur with the expert panel that resident lynx are very likely to persist in this unit at years 2025 and 2050, and likely to do so at 2100. Over the longer-term, we expect continued climate warming and associated impacts, perhaps especially increased wildfire activity, to reduce the amount and quality of lynx habitat in this unit, reducing lynx numbers and likely decreasing the population's resilience. Although the timing and extent of climate-mediated habitat decline is highly uncertain and fire-driven habitat loss typically would be temporary, wildfire size, frequency, and intensity have increased in this unit over the past few decades, and this pattern is expected to continue with projected climate warming.

Unit 4 - Atypically large, frequent, and intense wildfires over the past few decades have impacted over a third of the lynx habitat in north-central Washington, perhaps substantially more after additional fires in 2017. Because of this, the number of resident lynx in this unit is likely lower than it was historically and when the DPS was listed. Based on estimates of lynx carrying capacity, this unit may have been capable of supporting roughly 50-60 resident lynx prior to large fires beginning in the early 1990s. Recent habitat evaluations suggest it currently may be capable of supporting only about 30-35 lynx, with the decline due to fire-driven habitat losses. Although these losses are expected to be temporary, additional fires in this unit before previously burned areas recover (10-40 years post-burn) would further reduce lynx numbers and make this geographic unit more vulnerable to extirpation. Because of these habitat impacts, limited demographic information, and remaining uncertainties (e.g., immigration/emigration rates, changes in snowpack, disease, lynx population status and impacts of trapping in southern British Columbia, and habitat corridor stability between British Columbia and this unit), the Washington Department of Fish and Wildlife recently submitted, and the State Fish and Wildlife Commission adopted, a proposal to uplist lynx from threatened to endangered within the State. Nonetheless, we concur with the expert panel that the resident lynx population in this unit is very likely to persist at years 2025 and 2050. Over the longer-term (2100), we expect continued climate warming to reduce the amount and quality of lynx habitat in this unit, further reducing lynx numbers and likely decreasing the population's resilience. Therefore, we concur with experts that this unit has a relatively lower likelihood of supporting a resident population at 2100, although the timing and extent of climate-mediated habitat decline is highly uncertain.

Unit 5 – Based on evaluation of verified historic records, it is uncertain whether this geographic unit historically supported a small but persistent resident population or supported resident lynx only ephemerally. There are very few verified lynx records in the GYA from 1920-1999, but several resident lynx and evidence of reproduction were verified in the late 1990s and early 2000s (around the time the DPS was listed). In addition, at least 9 radio-marked lynx released in Colorado (see below) dispersed northward into or through this unit from 2003-2010, but no lynx have been detected in the GYA since 2010. Most places surveyed in Yellowstone National Park had hare densities clearly too low to support resident lynx. However, parts of the Wyoming Range south of the park, where many historical and most recent occurrences in this unit have been concentrated, had hare densities among the highest documented in the DPS range. No population estimates are available, but expert opinion suggests that this unit may only support 0-10 lynx, and we find no reliable evidence that it once supported a larger or persistent resident population. Therefore, given the uncertainty whether this unit historically or recently supported a persistent resident population and the lack of evidence that it is currently occupied by resident lynx, we concur with experts that it is very unlikely to support a resident population in the future.

Unit 6 – There are currently many more resident lynx in this unit than likely occurred historically, and many more than were known or suspected at the time the DPS was listed. There were even fewer verified records in this unit during the last century than in the GYA, and no reliable evidence of a resident breeding population. However, from 1999-2006, 218 Canadian and Alaskan lynx were released into the San Juan Mountains of southwestern Colorado. As a result of the subsequent reproduction of some of the released lynx and some of their offspring over several generations, resident lynx currently occupy this unit. When the DPS was listed in 2000, 27 of 41 lynx released in 1999 were still alive. The State of Colorado has concluded that its efforts have established a viable lynx population, and the State's lynx experts suggest this unit may currently support 100-250 resident lynx. Recent snow-tracking and camera surveys in the San Juan Mountains in the southern part of the unit documented evidence of continued lynx residency and reproduction. We concur with the expert panel that resident lynx in this unit are likely to persist at year 2025. However, given this unit's apparent historical inability to support a persistent resident population, its relative isolation from other lynx populations, its naturally fragmented habitat and generally very low hare densities, and its generally lower proportion of females producing kittens and low kitten survival, we believe it is less likely than expert projections to support a resident population at 2050 or at 2100. It is possible that hare densities will increase over the next several decades as large areas of forest regenerate from recent extensive insect and fire impacts. However, we expect any increase in hares to be temporary and accompanied by a longer-term insect- and fire-driven decrease in red squirrel (*Tamiasciurus hudsonicus*) abundance.

DPS Viability

In this SSA, we describe the current and future viability of the DPS in terms of resiliency, redundancy, and representation. Resident lynx populations persisted historically and continue to persist in 4 geographic units (Units 1-4). It is uncertain whether Unit 5 (the GYA) historically

supported a small persistent population or if lynx residency was ephemeral; currently, it appears not to support resident lynx. Available evidence suggests that Unit 6 (Colorado) did not historically support persistent lynx presence; however, a resident population has persisted there for more than a decade since the 1999-2006 releases described above. Considering the available information, we find no reliable evidence that the current distribution and relative abundance of resident lynx in the contiguous United States are substantially reduced from historical conditions. This suggests historical and current resiliency among lynx populations in the DPS.

The current broad distribution of resident lynx in large, geographically discrete areas (redundancy) makes the DPS invulnerable to extirpation caused by a single catastrophic event. Because we lack evidence that formerly persistent lynx populations have been lost from any large areas, it also seems that redundancy in the DPS has not been meaningfully diminished from historical levels. In fact, as a result of the current population in Colorado, redundancy in the DPS is likely greater, at least temporarily, now than it was historically.

Similarly, resident lynx remain broadly distributed across the range of habitats that has supported them historically, suggesting maintenance of the breadth and diversity of ecological settings occupied within the DPS range (representation). Additionally, observed high rates of dispersal and gene flow and, therefore, generally low levels of genetic differentiation across most of the lynx's range, including the DPS, suggest the past and recent genetic health of lynx populations in the DPS (representation; but see section 2.1). Because there are no indications of significant loss of or current stressors to the genetic health or adaptive capacity of lynx populations in the DPS, we find that the current level of representation within the DPS does not appear to indicate a decrease from historical conditions.

We expect lynx populations in each geographic unit to become smaller and more patchily-distributed due largely to projected climate-driven losses in habitat quality and quantity and related factors. However, the timing, rate, and extent of habitat decline due to projected climate warming and corresponding effects to lynx populations is highly uncertain. Despite some reduced resiliency, we conclude that resident lynx populations are very likely to persist in all 5 units that currently support them (Units 1-4 and 6) in the near-term (2025) and in all or most of those units at 2050, with corresponding maintenance of redundancy and representation in the DPS over that time span. We and the experts we consulted have low confidence in predicting the likely conditions of DPS populations beyond 2050. That said, smaller, more isolated populations would be less resilient and more vulnerable to demographic and environmental stochasticity and genetic drift and, therefore, at higher risk of extirpation. Although predictions out to 2100 are highly uncertain, it is possible that resident lynx populations could be functionally extirpated from some units by the end of the century. Should extirpations occur, this would indicate a loss of resiliency, reduced redundancy and representation, and an increased risk of extirpation of the DPS.

Chapter 1: Introduction

The Service designated Canada lynx in the contiguous United States as a DPS because of differences in the management of lynx and lynx habitats across the international boundary with Canada and because of the climatic, vegetative, and ecological differences in lynx habitat compared to the northern parts of the species' range in Canada and Alaska (62 FR 28654-28655). The Service listed the DPS as threatened under the ESA in 2000 because of the inadequacy, at that time, of existing regulatory mechanisms on some Federal lands to provide for the conservation of lynx habitats and populations (65 FR 16052-16086). On May 8, 2014, the United States District Court for the District of Montana ordered the Service to complete recovery planning for the lynx DPS (U.S. District Court MT 2014a, p. 8). On June 25, 2014, the same court ordered the Service to complete a recovery plan by January 15, 2018 "...unless the Service finds that such a plan will not promote the conservation of the [lynx]" (i.e., the DPS is recovered or no longer warrants ESA protections; U.S. District Court MT 2014b, p. 2). We completed this SSA (version 1.0) to summarize the best available scientific information on the current status and likely future viability of the DPS. This SSA will inform a determination by Service decision makers of whether (1) the DPS continues to warrant protection under the ESA and (2) a recovery plan is needed to guide conservation and recovery of the lynx DPS.

1.1 Background

The Canada lynx is a North American wild cat that is most strongly associated with northern-latitude boreal forests (taiga) of Canada and Alaska (McCord and Cardoza 1982, p. 729; Agee 2000, pp. 39-41; Aubry *et al.* 2000, pp. 373-374; Mowat *et al.* 2000, p. 272). It is a prey specialist and relies heavily on its primary prey, the snowshoe hare (*Lepus americanus*), to support survival, reproduction, recruitment, and, therefore, population persistence (Ruggiero *et al.* 2000a, p. 110; Mowat *et al.* 2000, p. 270; Steury and Murray 2004, pp. 128, 136-138; USFWS 2005, p. 2; Interagency Lynx Biology Team [ILBT] 2013, pp. 30-34; 79 FR 54808-54809). Lynx distribution and population persistence are also influenced by snow conditions (e.g., Peers *et al.* 2012, pp. 4-9). It is generally restricted to areas that receive deep and persistent unconsolidated ("fluffy") snow, which is thought to allow lynx, with their proportionately longer limbs and very large feet, to outcompete other terrestrial hare predators that are less efficient in such conditions (McCord and Cardoza 1982, pp. 748-749; Quinn and Parker 1987, p. 684; Buskirk *et al.* 2000a, pp. 89-94; Buskirk *et al.* 2000b, pp. 400-401; Ruggiero *et al.* 2000b, pp. 445-449; Hoving 2001, p. 75; Hoving *et al.* 2005, p. 744-749; Carroll 2007, entire; Gonzalez *et al.* 2007, entire; ILBT 2013, pp. 25-26; 79 FR 54809).

The lynx is generally considered secure, widespread, abundant, and distributed throughout most of its historical ranges in Canada and Alaska, which, combined, account for roughly 98 percent of the species' distribution. Lynx are distributed across approximately 5.5 million km² (2.1 million mi²) in Canada (Environment Canada 2014, p. 2) and 534,454 km² (206,354 mi²) in Alaska (Univ. of Alaska Center for Conservation Science 2016, entire; Reimer 2016, *pers. comm.*). The southern peripheries of the boreal forest and the distributions of snowshoe hares and lynx extend into the northern contiguous United States (Bittner and Rongstad 1982, p. 146;

McCord and Cardoza 1982, p. 729; Agee 2000, pp. 39-41; Aubry *et al.* 2000, pp. 379-382; Hodges 2000a, pp. 163-173; McKelvey *et al.* 2000a, pp. 242-253), where the 6 geographic units evaluated in this SSA represent the other 2 percent of the species' breeding distribution (approximately 131,168 km² [50,644 mi²]; see fig. 1, above, and table 2, below).

We consider "southern" lynx populations to include all those in the contiguous United States and in the southern parts of the adjacent Canadian provinces of (east to west) Nova Scotia, New Brunswick, Quebec (south of the Saint Lawrence Seaway and River), Ontario (north of the Great Lakes and Minnesota), Manitoba, Saskatchewan, Alberta, and British Columbia (e.g., see Ivan and Shenk 2016, p. 1051, fig. 1). Lynx populations in the DPS and on the margin of the range in adjacent Canadian provinces seem to function as peripheral subpopulations of a larger metapopulation that is broadly distributed across Canada and Alaska (McKelvey *et al.* 2000b, p. 25; 68 FR 40077; also see 2.2 below). The demographic and genetic health and persistence of DPS populations are thought to be influenced by connectivity with, and immigration of lynx from, larger populations in Canada (McKelvey *et al.* 2000b, pp. 21, 33; Schwartz *et al.* 2002, entire; 78 FR 59434, 59447; 79 FR 54815).

Lynx were documented historically in 24 of the Lower 48 States (McKelvey *et al.* 2000a, pp. 207-232), but records in many places are associated with cyclic "irruptions" of large numbers of lynx dispersing from southern Canada during the decline/low phase of snowshoe hare population cycles, roughly every 10 years. Many of these occurrences were in anomalous habitats, and lynx were unable to persist and establish populations in most of these areas (Gunderson 1978, entire; Thiel 1987, entire; McKelvey *et al.* 2000a, pp. 242, 253; Aubry 2006, pp. 1-2; ILBT 2013, p. 23; see also section 2.3.2). Habitats capable of supporting persistent resident lynx populations in the contiguous United States occur over a much smaller geographic area that includes parts of the Northeast (primarily northern Maine), western Great Lakes (northeastern Minnesota), Rocky Mountains (northern Idaho, northwestern Montana; perhaps also parts of northeastern Washington, the Greater Yellowstone Area (GYA) of southwestern Montana and northwestern Wyoming, and parts of western Colorado), and the eastern Cascade Mountains of northern Washington (68 FR 40077-40080; USFWS 2005, p. 3; 79 FR 54806-54807; Lynx SSA Team 2016a, pp. 6-7). Although uncertainty remains regarding the historical distribution of resident lynx in the contiguous United States, and small breeding populations may have been lost from some places, neither broad-scale breeding range contraction nor substantial changes in population status in the contiguous United States has been documented based on verified occurrence data (68 FR 40099; 72 FR 1187; 79 FR 54798, 54815; McKelvey *in* Lynx SSA Team 2016a, p. 11; also see section 2.3.2).

The Service designated lynx in the contiguous United States as a DPS and listed it as threatened under the ESA in 14 states in 2000 because of the inadequacy, at that time, of existing regulatory mechanisms on U.S. Forest Service (USFS) and Bureau of Land Management (BLM) lands in those states (65 FR 16052). In 2003, in response to a court memorandum opinion on the 2000 listing rule, the Service reaffirmed its determination of the lynx DPS and its status as threatened under the ESA (68 FR 40076). The Service completed a recovery outline in 2005 (USFWS 2005, entire), designated critical habitat for the DPS in 2006

(71 FR 66008) and, in 2007, again in response to a court order, clarified its determinations of “significant portion of the range” and that all lynx in the contiguous United States constitute a single DPS (72 FR 1186). Also in 2007, the Service announced that it would initiate a 5-year status review of the DPS (72 FR 19549). The Service revised the critical habitat designation for the DPS in 2009 (74 FR 8616) and 2014 (79 FR 54782) and, concurrent with the latter, rescinded the state-based definition of the DPS boundary to formally extend ESA protection to lynx “where found” in the contiguous United States, including New Mexico and other states that were not included in the original DPS range (79 FR 54804). Also in 2014 and as described above, the U.S. District Court for the District of Montana ordered the Service to complete a recovery plan for the lynx DPS by January, 2018, unless it finds that such a plan is not necessary. The Service reinitiated the 5-year status review in 2015 (USFWS 2015a, entire), and that review and potential recovery planning pursuant to it will be informed by this SSA report. On September 7, 2016, the U.S. District Court for the District of Montana remanded the 2014 critical habitat designation to the Service for further consideration (U.S. District Court MT 2016, entire).

The 6 geographic units evaluated in this SSA encompass all areas of the contiguous United States that currently support or are believed to have recently (since the DPS was listed in 2000) supported persistent resident lynx populations (fig. 1, above). Five of the 6 geographic units were designated as “Core Areas” in the Recovery Outline, and western Colorado was designated a “Provisional Core Area” (USFWS 2005, pp. 4-6, 21, 23). With the exception of western Colorado, the SSA units reflect the areas the Service designated as critical habitat in 2014 (79 FR 54782). Some areas adjacent to these geographic units are known or suspected to intermittently support resident lynx and occasional reproduction. Uncertainty remains as to whether resident lynx populations occurred historically in other areas not encompassed by the geographic units evaluated here.

The 6 geographic units include Federal, private, State, and Tribal lands, and proportions vary among the units, with private lands predominating in Maine, a mix of ownerships present in Minnesota, and Federal lands predominating in the western units (table 2).

Table 2. Lynx SSA Unit Sizes and Percent Ownership.

Unit ¹	Unit Size (km ²)	Percent of SSA Area	Land Ownership/Management (Percent) ²						
			Federal ³				Private	State	Tribal
			All Federal	USFS	NPS	BLM			
1	28,909	22.0	1.2	0	1.2	0	90.4	7.3	0.9
2	21,101	16.1	47.4	44.9	2.5	0.01	15.5	36.2	1.0
3	26,997	20.6	84.3	69.3	13.6	1.5	8.0	4.1	3.5
4	5,176	3.9	91.5	84.6	6.7	0.1	0.3	8.2	0
5	23,687	18.1	97.6	79.7	16.7	1.1	2.2	0.3	0
6	25,294	19.3	90.1	85.2	1.8	3.1	9.3	0.6	0
All Units	131,164	100	63.8	55.6	7.1	1.1	26.3	8.8	1.1

¹ Unit 1 - Northern Maine; Unit 2 - Northeastern Minnesota, Unit 3 - Northwestern Montana/Northeastern Idaho, Unit 4 - North-central Washington, Unit 5 - the Greater Yellowstone Area (Southwestern Montana/Northwestern Wyoming), Unit 6 - Western Colorado.

² Unit sizes and ownership for units 1-5 are those calculated for the areas designated in 2014 as lynx critical habitat, including some Tribal, State and private lands that met the criteria for critical habitat but which were excluded from the designation in accordance with section 4(b)(2) of the Endangered Species Act. Unit 6 size and ownership were calculated by the Service's Western Colorado Field Office in coordination with Colorado Parks and Wildlife based on telemetry data from radio-marked lynx.

³ USFS = U.S. Forest Service; NPS = National Park Service; BLM = Bureau of Land Management.

1.2 SSA Framework and Report

The Service is engaged in a number of efforts to improve the implementation of the ESA¹. As part of this effort, our Endangered Species Program has developed the Species Status Assessment (SSA) Framework to guide how we assess the best scientific and commercial data available when evaluating the biological status of species. The purpose of the SSA Framework is to provide a consistent, integrated, conservation-focused, and scientifically robust approach to assessing a species' biological status such that the information and analysis are useful to all decisions and activities under the ESA. The SSA does not result in a decision document; rather, it provides the biological information and scientific analysis in support of ESA decisions. The SSA Framework entails 3 iterative assessment stages (fig. 3; USFWS 2016a):

¹ See: http://www.fws.gov/endangered/improving_ESA/.

1. **Species' Needs.** An SSA begins with a compilation of the best available biological information on the species (taxonomy, life history, and habitat) and its ecological needs at the individual, population, and species levels based on how environmental factors are understood to act on the species and its habitat.

2. **Current Species' Condition.** Next, an SSA describes the current condition of the species' habitat and demographics, and the probable explanations for past and ongoing changes in abundance and distribution within the species' ecological settings (i.e., areas representative of the geographic, genetic, or life history variation across the species' range).

3. **Future Species' Condition.** Lastly, an SSA forecasts the species' response to probable future scenarios of environmental conditions and conservation efforts. As a result, the SSA characterizes species' ability to sustain populations in the wild over time (viability) based on the best scientific understanding of current and future abundance and distribution within the species' ecological settings.

Throughout the assessment, the SSA uses the conservation biology principles of resiliency, redundancy, and representation (collectively known as the "3 Rs") as a lens to evaluate the current and future condition of the species. Resiliency describes the ability of the species to withstand stochastic disturbance events, which is associated with population size, growth rate, and habitat quality. Redundancy describes the ability of a species to withstand catastrophic events, which is related to the number, distribution, and resilience of populations. Representation describes the ability of a species to adapt to changing environmental conditions, which is related to distribution within the species' ecological settings. Together, the 3 Rs, and their core autecological parameters of abundance, distribution and diversity, comprise the key characteristics that contribute to a species' ability to sustain populations in the wild over time. When combined across populations, they measure the health of the species as a whole.

The Species Status Assessment Report (SSA Report) is a summary of the information assembled, reviewed, and assessed by the Service and is based on the best scientific and commercial data available at the time of the assessment. Completed SSA Reports and supporting material can be found at the collaborative repository of the National Park Service and the USFWS called "ServCat"².

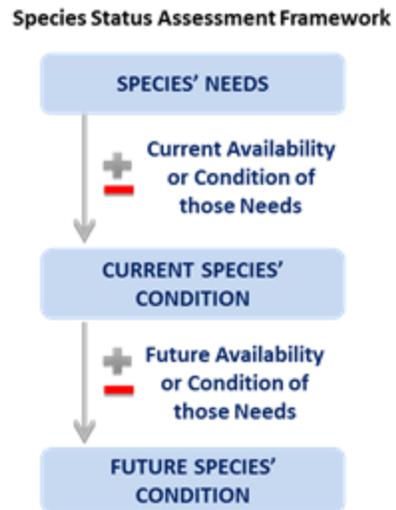


Figure 3. SSA Framework stages.

² <http://www.fws.gov/Refuges/NaturalResourcePC/landM/serviceCatalog.html>.

1.3 Analytical Approach and Methods

We used the SSA Framework described above to evaluate the current status of resident lynx in the contiguous United States as well as the likelihood that the geographic areas supporting resident lynx in the DPS would continue to do so in the near-term and at mid- and end-of-century (years 2025, 2050, and 2100). We framed our evaluation in terms of the 3 Rs using conceptual modeling (figs. 4-7) based on available published literature, other information on the historical and current status of and threats to lynx in the DPS and, where empirical data are lacking, on formally-elicited expert opinion and best professional judgment (Lynx SSA Team 2016a, entire). The conceptual models below are intended to broadly highlight important relationships thought to influence lynx in the DPS in terms of representation, redundancy, and resiliency. They are not meant to capture every nuance of all possible relationships between lynx and their environments or to illustrate all factors potentially capable of affecting individual lynx or populations.

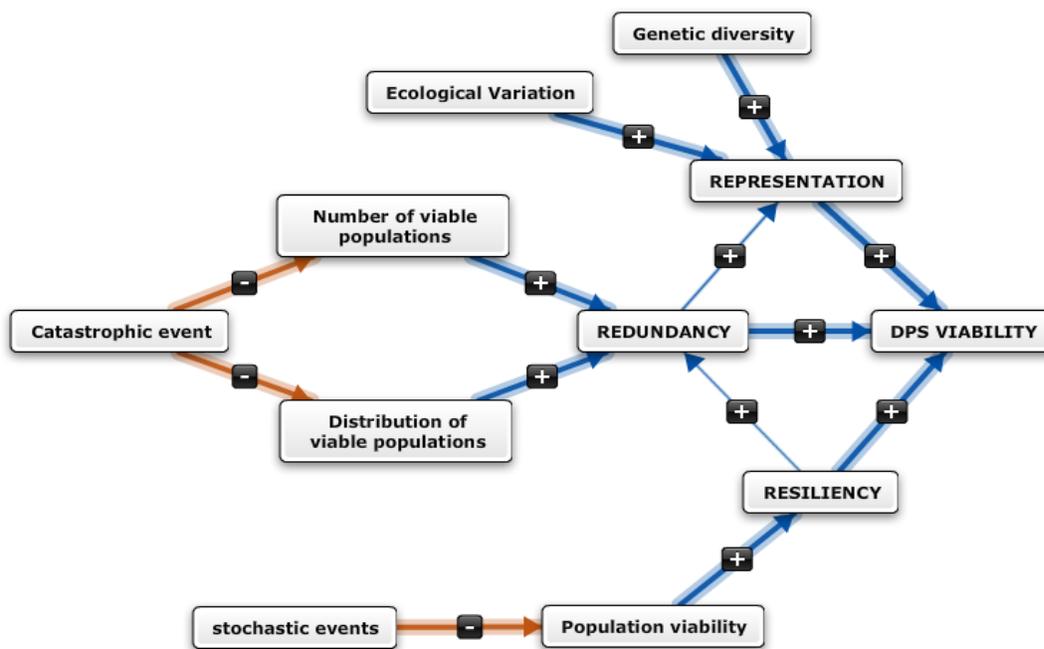


Figure 4. Conceptual model of the factors thought to influence the 3 Rs as they pertain to lynx viability.

We applied the definitions from the SSA Framework for the principles of redundancy, representation, and resiliency, provided in section 1.2, to Canada lynx as described below. We evaluated redundancy and representation at the scale of the DPS as a whole, and resiliency at the scale of lynx populations within each of the 6 geographic units and at the scale of the DPS as a whole.

To evaluate **redundancy** for the lynx DPS, we considered the current and likely future geographic distributions of resident breeding populations and whether the DPS is currently vulnerable to extirpation from a catastrophic event or would be vulnerable in the future. We

consider catastrophic events to be relatively discrete in both time and geographic extent (e.g., wildfires, storms, floods, volcanic eruptions, etc.) and, therefore, we do not consider anthropogenic climate warming as a catastrophic event (see below). Figure 5 shows examples of relationships among factors that may influence redundancy within the lynx DPS.

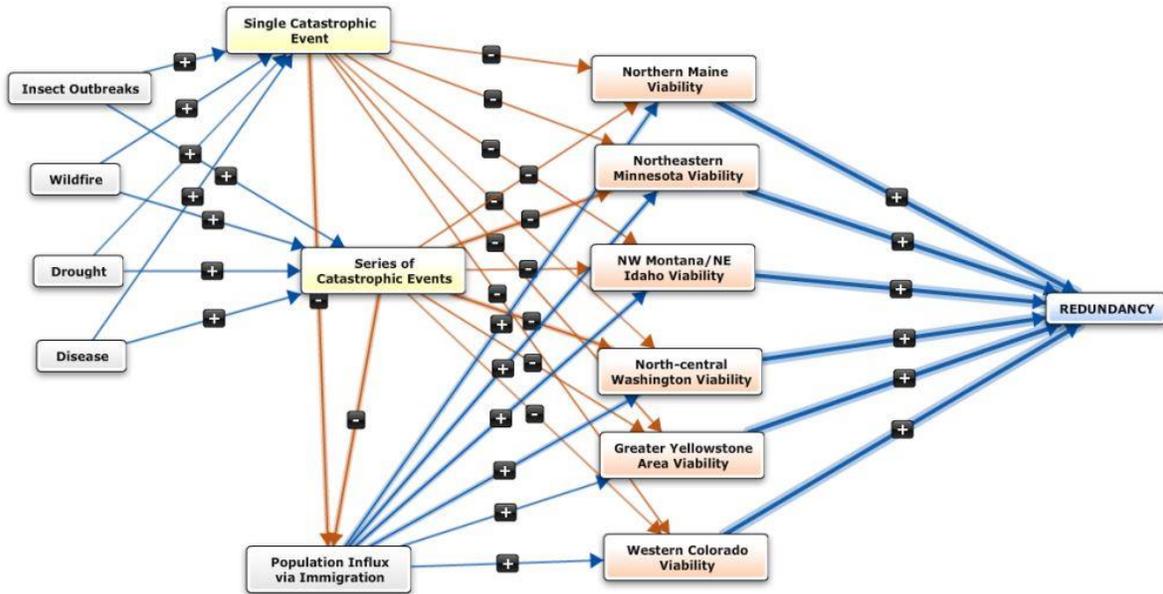


Figure 5. Conceptual model of factors thought to influence redundancy within the lynx DPS.

To evaluate **representation** for the lynx DPS, we considered measures of genetic diversity and heterozygosity, the current and likely future ecological diversity (breadth) of geographic areas occupied by resident breeding populations, and the documented dispersal capabilities of the species, as shown in figure 6 below.

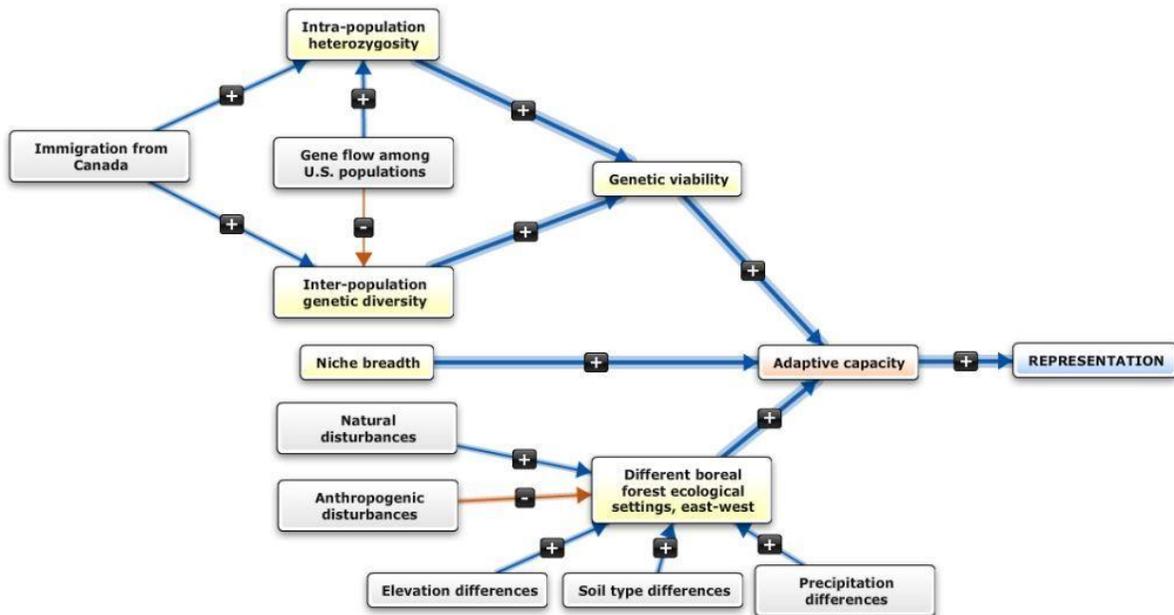


Figure 6. Conceptual model of factors thought to influence representation within the lynx DPS.

Because we lack reliable estimates of the sizes and trends of lynx populations in the DPS and existing demographic data are inadequate to construct empirical models to project population sizes, trends, and viability into the future, our evaluation of the **resiliency** of lynx populations in the DPS was based largely on consideration of recent status updates and formally-elicited expert opinion regarding the likelihood that DPS populations will remain viable into the future. The relationships among factors that influence DPS resiliency are shown in figure 7 below.

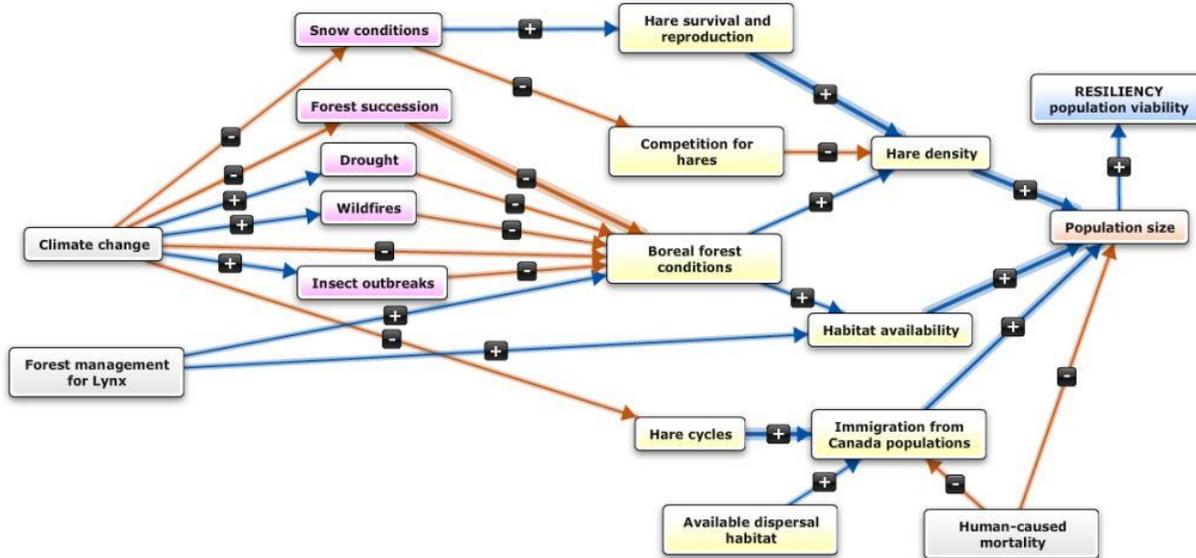


Figure 7. Conceptual model of factors thought to influence the resiliency of lynx populations within the DPS.

We elicited expert input on the current status of resident lynx populations in each geographic unit and the likelihood that each unit would continue to support them in the future (i.e., that resident populations would not be functionally extirpated [reduced to the point that a viable breeding population could no longer be sustained]). To assess both current and future conditions for lynx in the DPS, we considered the adequacy of existing regulatory mechanisms (the factor for which the DPS was originally listed) as well as the anthropogenic influences considered by the Interagency Lynx Biology Team (ILBT) to have the potential to exert population-level (3 Rs) effects on the DPS (climate change, vegetation management, wildland fire management, and habitat loss and fragmentation; ILBT 2013, pp. 68-78).

In Chapter 4, we present our assessment of current conditions based on expert input and our evaluation of the available scientific information regarding lynx populations and habitats and the influencing factors described above for each geographic area. In Chapter 5, we present summaries of experts' predictions regarding the probability of lynx persistence in each geographic unit; the factors they thought would most likely influence those probabilities; and the sources of uncertainty that influenced their confidence in their predictions. We then present our evaluation of the scientific literature regarding how certain anthropogenic factors may influence future conditions for resident lynx in each geographic unit. Other factors were also evaluated for some geographic units if the SSA Core Team member most familiar with that unit felt those factors could pose meaningful, even if less likely, risks to the unit's continued ability to support resident lynx. After considering all of the above, we present our conclusions regarding the future conditions for resident lynx in each geographic unit and we discuss the extent to which our conclusions agree with or differ from the projections provided by the lynx expert panel we consulted, and if they differed, why.

Implicit in our evaluation of the future for lynx in the contiguous United States is our recognition and consideration of a possible future in which the DPS is not listed under the ESA. However, we do not evaluate the unlikely hypothetical future in which all protections and conservation efforts would disappear if the DPS was not listed given (1) the history of lynx management, research, monitoring, and habitat conservation efforts by State wildlife and natural resource agencies in most states throughout the DPS range; (2) similar efforts by Federal land managers and related formal amendments or revisions to most of their land management plans to address the threat for which the DPS was listed (the inadequacy of previous Federal regulatory mechanisms); (3) Tribal lynx conservation efforts and wildlife management philosophies; and (4) the DPS's listing and consultation history. Rather, we assume that although some protections could be relaxed (e.g., less stringent analyses of Federal project-related impacts, potential for some states to reinstitute limited lynx trapping/hunting harvest, reduced incentives for lynx conservation efforts on some private lands), Federal, State, Tribal and some private land managers would continue efforts to conserve lynx and its habitats and to assure persistence of resident lynx populations in those places that can support them in the DPS range. Our evaluation, therefore, considers the possibility of the future relaxing of some lynx conservation measures and efforts should the DPS be delisted, but not the complete absence of all protections for lynx.

Additionally, we do not define and evaluate specific and explicit climate change or greenhouse gas emissions scenarios or attempt to quantify differences in DPS viability or the persistence of resident lynx populations in individual geographic units based on differences in the rate and extent of potential impacts associated with projected continued climate warming. This is because of the limited resolution and inherent uncertainty of available climate models and the inadequacy of existing demographic data for projecting lynx populations in the DPS over time, including their potential responses to a range of climate-mediated potential future habitat conditions. Therefore, this SSA does not constitute or include a formal climate change vulnerability assessment (Glick *et al.*, editors, 2011, entire) for the lynx DPS. Instead, underlying our evaluation in this SSA is the recognition 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 (see sections 1.4 and 3.2 below). Therefore, we (along with the experts we consulted and the ILBT) consider lynx populations in the DPS vulnerable (predisposed to be adversely affected; IPCC 2014a, p. 5) to the projected impacts climate change. While we recognize that the pace and extent of impacts would be expected to differ under specific emissions or modeling scenarios, the limitations described above preclude us from quantifying those differences and their potential influence on the likelihood that resident lynx populations will persist in the DPS or in individual geographic units. Finally, in our analyses we do not consider anthropogenic climate warming a catastrophic effect because it is not temporally- and spatially-discrete; characteristics of events traditionally considered catastrophic (e.g., wildfires, floods, storms, volcanic eruptions, etc.). Rather, we consider climate change as an ongoing, pervasive, and cumulative stressor of lynx and their habitats, particularly at the southern margin of the species' distribution, including all geographic areas of the DPS.

1.4 Uncertainties and Assumptions

Several sources of uncertainty had to be accounted for in our analysis, including the paucity of empirical data on lynx population sizes, trends, and other important demographic parameters in the DPS; the influence of immigration of lynx from Canada on the persistence of DPS populations; the effectiveness of habitat management efforts; and the effects of competition on lynx populations. We similarly lack demographic information for snowshoe hares throughout much of the DPS range, and consistent methods to monitor hare and lynx habitats and populations have not been implemented throughout most of the range. And importantly, given the emerging role of climate change as a stressor, uncertainties about the rate and extent of projected future impacts to boreal, subalpine, and montane forests and snow quality, depth, and persistence constrain our ability to precisely predict effects on lynx and hare populations and habitats, including to what degree these changes may affect interactions between lynx and their potential competitors.

To account for these uncertainties in our analysis, we identified a number of critical assumptions based on the scientific literature and input provided by the lynx experts we consulted. We treated the following assumptions as constants in the analysis.

- We assume that, in general, habitat quality and contiguity and hare densities are naturally lower at the southern margin of the lynx's range (in both the contiguous United States and the southern portions of adjacent Canadian provinces) compared to the core of the species' range in Canada and Alaska. Hare populations in the DPS range are noncyclic or weakly cyclic and, although they do not exhibit the dramatic cyclic declines of their northern counterparts, they typically occur at densities on the lower end of those in the northern range. Because of this, lynx densities in most of the DPS range are typically similar to those in the north during hare cycle lows.
- We assume that, as a consequence of generally lower habitat quality and hare densities, only some places within the DPS range are capable of supporting persistent resident lynx populations, while others may naturally support resident lynx only ephemerally, and yet other areas are naturally incapable of supporting resident lynx despite boreal-forest-like vegetation, the presence of some hares, and the occasional or intermittent presence of dispersing or transient lynx.
- We assume that the statuses of lynx populations in individual SSA geographic units are largely independent of those in the other geographic units. This is clearly true for Units 1 and 2, and it is probably true of the western geographic units (3 – 6), despite likely historical north-to-south connectivity and dispersal from or through Unit 3 to Unit 5 and possibly Unit 6, and recent evidence of south-to-north connectivity and dispersal from Unit 6 to and through Units 5 and 3. We are aware of no evidence of east-west connectivity or dispersal between Units 3 and 4.

- We assume that lynx populations in the DPS occur as the southern extensions of larger, cross-border populations or as relatively isolated subpopulations of the larger Canadian populations.
- We assume that lynx exhibit a metapopulation structure in which populations at the southern periphery of the species' range (including all DPS populations and some in southern Canada) receive periodic immigration of lynx dispersing from populations in the core of the Canadian range.
- We assume that connectivity with lynx populations in Canada is important, and that periodic immigration of lynx into the DPS from Canada contributes to the persistence of DPS populations, although the extent to which the demographic and genetic health of DPS populations may depend on immigration remains uncertain.
- We assume that (1) the lynx's morphology confers a competitive advantage in snowy conditions over other terrestrial hare predators, (2) snow conditions (depth, consistency, and persistence) influence the distribution of lynx and its potential terrestrial competitors, and (3) in the absence or loss of these conditions, lynx could be displaced by other terrestrial hare predators.
- We assume that the lynx, as a boreal forest- and snow-associated predator that relies heavily on a single, similarly-specialized prey species, and whose habitats are influenced by climate-mediated disturbance factors (e.g., wildfire, forest insects, wind/ice storms), is highly sensitive and broadly exposed to the impacts of climate warming and has limited adaptive capacity to respond to it. That is, despite some level of behavioral plasticity suggested by differences in snow conditions and specific vegetation communities and stand conditions across the DPS range, we expect that lynx lack the adaptive capacity to shift to non-boreal (e.g., temperate coniferous or deciduous) forests, non-snow-dominated climates, or to persist on alternate prey species where hare densities are or become inadequate. Therefore, we assume lynx populations in the DPS are vulnerable (sensitive, exposed, and with little capacity to adapt; therefore, predisposed to be adversely affected; IPCC 2014a, p. 5) to the projected impacts of continued climate warming.
- We assume that lynx conservation measures and habitat management guidance adopted by the USFS and the BLM via formally amended or revised management plans or conservation agreements with the Service have had a positive influence on DPS lynx populations that occur on Federal lands and will continue to provide benefits as long as those measures and guidance are implemented.
- We assume that the DPS could be delisted in the future and that some of the current protections afforded by the ESA could be lost and/or relaxed. However, we assume that Federal, State, and Tribal agencies and some private landowners would continue to manage for the conservation of resident lynx populations in those places that can support them in the DPS range.

For purposes of the SSA, we forecast potential future conditions for lynx in the DPS through the end of this century, and we asked a panel of 10 lynx experts to provide their opinions on the likelihoods that each geographic unit would support resident lynx populations over the short-term (year 2025), mid-term (2050) and longer-term (2100). As expected, the level of uncertainty regarding the viability of the DPS and each of the factors that may influence it increases the farther into the future we (and the lynx experts we consulted) try to look, and this uncertainty greatly reduces confidence in future projections, particularly beyond mid-century. Beyond that time frame, uncertainty regarding the potential impacts of climate change and other potential stressors to lynx populations in the DPS becomes so great that it precludes meaningful analysis or reliable predictions regarding viability.

Finally, although formal elicitation of expert opinion where empirical information is unavailable or inadequate is an appropriate and scientifically supported approach, we remind readers that the output remains the experts' best professional judgment, which is subjective and, therefore, inherently different than experimentally collected data subjected to rigorous statistical analyses. For purposes of useful and meaningful presentation and comparison among geographic units, it was necessary to combine, quantify, graph, and summarize the qualitative information provided by experts. However, we caution that the results we present, graph, and describe in chapter 5 should not be interpreted as precise, statistically robust estimates of the probability that resident lynx will persist in the DPS or in any individual geographic unit in the future, and readers should consider the inherent limitations and substantial uncertainties in expert responses, particularly over longer time periods.

Chapter 2: Lynx Ecology

In this chapter, we describe the physical characteristics, taxonomy, and genetics of the Canada lynx, its life history and population dynamics, and its taxon-wide and DPS distributions. We rely heavily on recent summaries of this information provided in the revised *Canada Lynx Conservation Assessment and Strategy* (LCAS; ILBT 2013, entire), the Service's recent proposed (2013) and final (2014) rules to revise the designation of critical habitat for the DPS (78 FR 59430-59474; 79 FR 54782-54846), and the results of the October 2015 Canada Lynx Expert Elicitation Workshop (Lynx SSA Team 2016a, entire). We also provide a summary of the pertinent ecological requirements of lynx at the individual, population, and DPS levels. These ecological requirements form the basis of our analyses conducted in Chapters 3 through 5.

2.1 Species Taxonomy, Description, and Genetics

The Canada lynx (order Carnivora; family Felidae) is 1 of 4 species within the genus *Lynx* (Kerr 1792), which also includes the bobcat (*L. rufus*, Schreber 1777), the Eurasian lynx (*L. lynx*, Linnaeus 1758), and the Iberian or Spanish lynx (*L. pardinus*, Temminck 1827). There are 3 recognized subspecies of Canada lynx: *Lynx canadensis canadensis* (Kerr 1792), *L. c. mollipilosus* ("Arctic lynx," Stone 1900), and *L. c. subsolanus* ("Newfoundland lynx," Bangs

1897; Integrated Taxonomic Information System online database³, retrieved April 14, 2016). The Canada lynx is believed to have evolved from the Eurasian lynx in the last 200,000 years in North America as a snowshoe hare specialist (Werdelin 1981, p. 69).

The Canada lynx is a medium-sized cat with long legs and large, well-furred paws. In winter, the lynx's fur is dense and has a grizzled appearance with a grayish-brown mix of buff or pale brown fur on the back, and a grayish-white or buff-white fur on the belly, legs, and feet. In summer, its fur is more reddish to gray-brown (McCord and Cardoza 1982, p. 730). It has long tufts of black hairs extending from the tips of its ears, a short, completely black-tipped tail, and often a distinct dish-like facial ruff of pale hairs tipped black. Lynx generally measure 75 to 90 cm (30 to 35 in) long and weigh 6 to 14 kg (14 to 31 lb; Quinn and Parker 1987, table 1; Moen *et al.* 2010a, fig. 2; MDIFW 2012, *unpubl. data*), and males are 13-25 percent larger than females (Mowat *et al.* 2000, p. 267). The lynx's large feet and long legs make it well-adapted for traversing and hunting in deep, powdery snow, where its low foot-loading (weight per surface area of foot) is thought to provide a competitive advantage (Buskirk *et al.* 2000a, p. 90; 2000b, p. 400; ILBT 2013, pp. 26, 36, 81) over other terrestrial predators of snowshoe hares, the lynx's primary prey. In southern Canada and the northern contiguous United States, where the southern edge of the lynx range overlaps the northern edge of the bobcat range, the 2 species are easily confused because of their similar size and appearance. However, the lynx's longer ear-tufts, larger feet, and black-tipped tail distinguish it from the bobcat, which has shorter ear tufts, small feet, and white on the underside of the tail. Bobcats are much more common, widespread, and abundant than lynx in most of the contiguous United States.

Overall, genetics research suggests high gene flow across most of the continental range of lynx, likely because of high dispersal rates, large dispersal distances, and the absence of significant barriers to genetic interchange throughout much of the lynx range, including the DPS (Schwartz *in* Lynx SSA Team 2016a, pp. 11-12). Genetic evidence also indicates interactions between lynx populations even where physical barriers appear most likely to restrict gene flow. For example, although *L. c. subsolanus* on Newfoundland Island is genetically (Row *et al.* 2012, pp. 1262-1266; Koen *et al.* 2015, p. 528) and morphologically (Khidas *et al.* 2013, pp. 597-601) distinct from mainland lynx (*L. c. canadensis*), there is evidence of genetic exchange between the 2 areas, indicating that some lynx are able to cross the 15-60 km- (9-37 mi-) wide Strait of Belle Isle that separates them (Koen *et al.* 2015, p. 527). Similarly, despite some differences in functional genetic markers (unique alleles) in lynx south versus north of the St. Lawrence Seaway/River in eastern Canada, which suggest the potential for evolutionarily significant differences in those areas (Bowman *in* Lynx SSA Team 2016a, p. 14), recent analyses reveal genetic exchange among lynx on either side, indicating that some lynx successfully navigate this barrier (Koen *et al.* 2015, pp. 524-528; Bowman *in* Lynx SSA Team 2016a, p. 12-13). However, Prentice *et al.* (2017, entire) documented natural selection for unique alleles in relatively isolated island populations of lynx in eastern Canada.

Schwartz *et al.* (2003, entire) documented reduced genetic variation (lower mean number of alleles per population and lower expected heterozygosity) among peripheral lynx populations

³ <http://www.itis.gov>.

compared to populations in the core of the lynx geographical range in Canada and Alaska. While recognizing that small changes in genetic variation can lead to large changes in population fitness, the authors noted that the differences between core and peripheral populations in their study were small enough to suggest a lack of significant population subdivision (i.e., no indication of genetic isolation, substantial genetic drift, or potential genetic “bottlenecks” among DPS populations; Schwartz *et al.* 2003, p. 1814; 79 FR 54793). This finding is consistent with their earlier work, which documented high levels of gene flow (the highest yet documented for any carnivore) between core and peripheral lynx populations despite large separation distances (Schwartz *et al.* 2002, entire). Their results did not suggest that reduced genetic variation among peripheral populations was because of human disturbance (i.e., habitat loss/fragmentation on the southern periphery of the geographic range; Schwartz *et al.* 2003, p. 1814), but the authors concluded that the persistence of lynx populations in the contiguous United States depends on dispersal from larger (core) populations (Schwartz *et al.* 2002, p. 522).

Within the contiguous United States, minor genetic sub-structuring has been documented among lynx subpopulations in western Montana (Schwartz *in* Lynx SSA Team 2016a, p. 12 and Appendix 5). Genetic diversity may be somewhat greater among lynx in western Colorado than elsewhere in the DPS range because of the broad geographic distribution of the source populations that contributed to the lynx releases in Colorado (45 lynx from Quebec, 4 from Manitoba, 91 from British Columbia, 48 from The Yukon Territory, and 30 from Alaska). Additionally, lynx-bobcat hybridization has been documented in Minnesota, Maine, and New Brunswick (Schwartz *et al.* 2004, entire; Homyack *et al.* 2008, entire), where male bobcats bred with female lynx to produce fertile offspring with lynx-like ear tufts, intermediate foot-size, and bobcat-like fur (ILBT 2013, p. 35). In Minnesota from 2000 to 2015, DNA analyses documented 13 distinct hybrid individuals (Moen and Catton *in* Lynx SSA Team 2016a, pp. 13, 19); hybrids have yet to be documented in the western portion of the lynx’s range (Schwartz *in* Lynx SSA Team 2016a, p. 12). At a continental scale, Koen *et al.* (2014b, pp. 111-113) found a low level of bobcat-lynx genetic introgression (i.e., hybridization) but suggested it could increase if bobcat distribution shifts northward in the future as a result of continued climate warming (also see section 3.2 below).

Currently, there is no indication that the levels of connectivity and gene flow between lynx populations in the DPS and those in the core of the lynx’s range are inadequate to maintain the genetic health of DPS populations. Given the connectivity of most DPS units with lynx populations and habitats in Canada (particularly Units 1-4, which have the strongest evidence of historically persistent resident lynx populations), the noted dispersal capabilities of lynx, evidence of dispersal in both directions across the Canada-United States border (Aubry *et al.* 2000, pp. 386-387; Squires *et al.* 2006a, p. 38; Moen *et al.* 2010b, pp. ii, 17, 19; Vashon *et al.* 2012, p. 22), and the small number of immigrants thought necessary to maintain genetic variability in peripheral populations (McKelvey *et al.* 2000b, pp. 23-24), genetic isolation, biologically meaningful genetic drift, or potential genetic “bottlenecks” appear unlikely among most DPS populations in the near future (79 FR 54793). However, the potential for genetic drift would be expected to increase at some point in the future if lynx and hare habitats shift

northward and upslope, as projected with continued climate warming, resulting in reduced connectivity and gene flow among smaller and more isolated lynx populations at the periphery of the range (Schwartz 2017, pp. 4-5; also see section 3.2).

2.2 Life History and Population Dynamics

All aspects of lynx life history are inextricably tied to its primary prey, the snowshoe hare (fig. 8), which comprises most of the lynx diet throughout its range (Nellis *et al.* 1972, pp. 323–325; Brand *et al.* 1976, pp. 422–425; Koehler and Aubry 1994, pp. 75, 85; Apps 2000, pp. 358–359, 363; Aubry *et al.* 2000, pp. 375–378; Mowat *et al.* 2000, pp. 267–268), including the DPS (Koehler 1990a, p. 848; von Kienast 2003, pp. 37–38; Squires *et al.* 2004a, p. 15, table 8; Moen 2009, p. 7; Vashon *et al.* 2012, p. 11; Olson 2015, pp. 60-69; Ivan and Shenk 2016, p. 1053). Lynx are highly specialized hare predators and require landscapes that consistently support relatively high hare densities (McCord and Cardoza 1982, p. 744; Quinn and Parker 1987, pp. 684-685; Aubry *et al.* 2000, pp. 375-378).

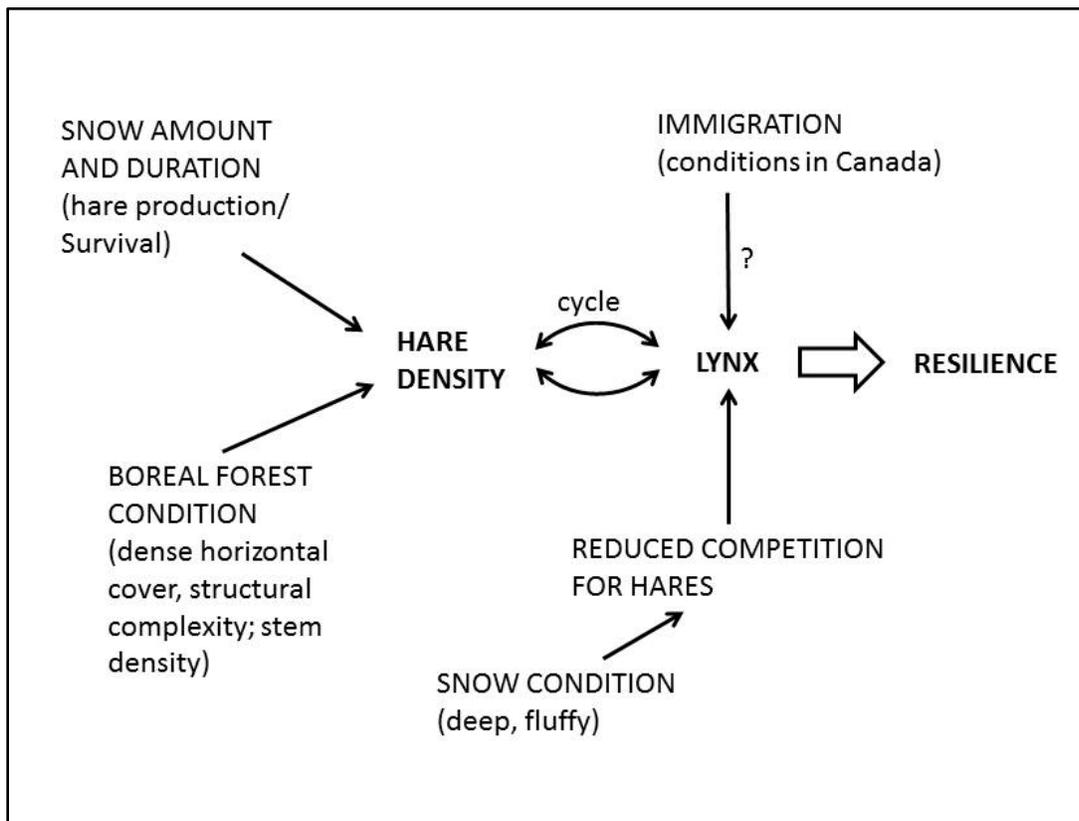


Figure 8. Generalized relationship between habitat conditions and hare and lynx population dynamics and their influence on lynx population resiliency.

Although lynx take a variety of alternate prey species, especially red squirrels (*Tamiasciurus hudsonicus*), which may be important when hare numbers are low (O'Donoghue *et al.* 1997, pp. 154-155; 1998, pp. 1198-1205; Ivan and Shenk 2016, pp. 1054-1056), hare abundance is the major driver of lynx population dynamics. Lynx denning area selection, pregnancy rates and

litter sizes, as well as survival (kitten, subadult, and adult), recruitment, and dispersal rates, and population age structure, home range sizes, density, and distribution are all strongly influenced by hare abundance (Koehler and Aubry 1994, pp. 75-76, 80-83; Apps 2000, entire; Aubry *et al.* 2000, pp. 375-390; Mowat *et al.* 2000, pp. 270-294; Moen *et al.* 2008a, p. 1507; Organ *et al.* 2008, p. 1516; Vashon *et al.* 2012, p. 16; ILBT 2013, pp. 18, 22-24, 26-34).

Lynx and snowshoe hares are strongly associated with moist boreal forests, where winters are long, cold, and snowy (Bittner and Rongstad 1982, p. 154; McCord and Cardoza 1982, p. 743; Quinn and Parker 1987, p. 684-685; Agee 2000, p. 39-47; Aubry *et al.* 2000, pp. 373-382; Hodges 2000a, pp. 183-191; 2000b, pp. 136-140; McKelvey *et al.* 2000a, pp. 211-232). The predominant vegetation of boreal forest is conifer trees, primarily species of spruce (*Picea* spp.) and fir (*Abies* spp.; Elliot-Fisk 1988, pp. 34-35, 37-42). Snowshoe hares feed on conifers, deciduous trees, and shrubs (Hodges 2000a, pp. 181-183) and are most abundant in forests with dense understories that provide forage, cover to escape from predators, and protection during extreme weather (Wolfe *et al.* 1982, pp. 665-669; Litvaitis *et al.* 1985, pp. 869-872; Hodges 2000a, pp. 183-195; 2000b, pp. 136-140). Lynx population dynamics, survival, and reproduction are closely tied to snowshoe hare availability, making snowshoe hare habitat the primary component of lynx habitat. However, lynx do not occur everywhere within the range of snowshoe hares in the contiguous United States (Bittner and Rongstad 1982, p. 146; McCord and Cardoza 1982, p. 729). This may be due to inadequate abundance, density, or spatial distribution of hares in some places, or the absence of snow conditions that would provide lynx a competitive advantage over other terrestrial hare predators (see below), or a combination of these factors (79 FR 54809).

The boreal forest landscapes lynx and hares occupy are naturally dynamic. Forest stands within the landscape may experience abrupt changes after natural or human-caused disturbances such as fire, insect outbreaks, wind, ice, disease, and forest management (e.g., timber harvest or thinning) and more gradual changes as they undergo succession and regenerate after such events (Elliot-Fisk 1988, pp. 47-48; Agee 2000, pp. 47-69). As a result, lynx habitat is a shifting mosaic of forest patches of variable ages and changing quality (68 FR 40077). These stands of differing ages and conditions provide lynx foraging or denning habitat (or may provide these in the future depending on patterns of disturbance and forest succession), and some serve as travel routes for lynx moving between foraging and denning habitats (McKelvey *et al.* 2000c, pp. 427-434; Hoving *et al.* 2004, pp. 290-292).

Over much of the lynx's range, hare densities are higher in regenerating, earlier successional forest stages because they often have greater understory structure (dense horizontal cover) than mature forests (Buehler and Keith 1982, p. 24; Wolfe *et al.* 1982, pp. 665-669; Koehler 1990a, pp. 847-848; Hodges 2000a, pp. 183-195; Homyack 2003, pp. 63, 141; Griffin 2004, pp. 84-88). However, snowshoe hares also can be abundant in mature forests with dense horizontal cover, particularly in the Northern Rocky Mountains (Griffin 2004, pp. 53-54; Griffin and Mills 2009, pp. 1492-1496; Hodges *et al.* 2009, p. 876; Squires *et al.* 2010, pp. 1653-1657; Berg *et al.* 2012, pp. 1483-1487). These mature forests may be a source of hares for other adjacent forest types (Griffin and Mills 2009, pp. 1492, 1495-1496), and they may provide especially important

winter foraging habitats (Squires *et al.* 2010, pp. 1655-1657), which may be the most limiting habitat for lynx (Squires *et al.* 2010, pp. 1655-1657; ILBT 2013, pp. 17, 27). They also are more temporally-stable (i.e., they provide high-quality hare habitat for a longer period of time) than regenerating stands, which may foster high hare densities for a variable window of time between stand-initiation and stem-exclusion stages of succession, after which older regenerating stands may persist, in the absence of disturbance, for many years as lower-quality hare habitat (ILBT 2013, pp. 62, 71, 127).

Lynx generally concentrate hunting activities in areas where snowshoe hare densities are high (Koehler *et al.* 1979, p. 442; Ward and Krebs 1985, pp. 2821-2823; Murray *et al.* 1994, p. 1450; O'Donoghue *et al.* 1997, pp. 155, 159-160 and 1998, pp. 178-181), but several studies showed that lynx focused foraging efforts in stands with intermediate hare densities and forest structural complexity that occurred at the edges of the highest density habitat, suggesting that lynx must balance between hare abundance and accessibility (Fuller and Harrison 2010, pp. 1276–1277; Simons-Legaard *et al.* 2013, p. 574). Because understory density within a forest stand changes over time, hare habitat quality and corresponding hare densities also shift over time across boreal forest landscapes.

Hare populations in the core of the lynx range in Canada and Alaska undergo well-documented dramatic 8 to 11 year cycles during which hare numbers may fluctuate 10 to 25 fold or more, with peak densities as high as 23 hares/hectare (ha; 9.3 hares/acre [ac]) and lows of 0.1 hares/ha (0.04 hares/ac; Hodges 2000b, pp. 117-121; Vashon 2015, p. 4). Hare densities are generally lower at the southern periphery of lynx distribution, and hare population cycles are generally much less pronounced or absent entirely among some hare populations in southern Canada and in the contiguous United States (Hodges 2000a, pp. 163–173; Hodges *et al.* 2009, pp. 870, 875–876; Scott 2009, pp. 1–44; Environment Canada 2014, p. 1; Hodges *in* Lynx SSA Team 2016a, pp. 16-17). In the contiguous United States, average stand-level hare densities may exceed 2 hares/ha (0.8 hares/ac; Walker 2005, pp. 20, 85; McCann 2006, p. 15; Robinson 2006, pp. 26-36, 62-75; Homyack *et al.* 2007, pp. 10-11; Griffin and Mills 2009, p. 1492; Vashon *et al.* 2012, p. 14), but in many parts of the DPS, landscape-level densities are lower, ranging from just above to well below the 0.5 hares/ha (0.2 hares/ac) density thought necessary to sustain lynx home ranges and populations (Hodges 2000a, pp. 168-169, 185; Ruggiero *et al.* 2000b, pp. 446–447; Squires and Ruggiero 2007, pp. 313-314; Maletzke *et al.* 2008, pp. 1476-1477; Zahratka and Shenk 2008, pp. 910-911; Hodges *et al.* 2009, pp. 873-877; Ivan 2011a, pp. 91-92, 95-102; Berg *et al.* 2012, p. 1483; ILBT 2013, pp. 24, 26, 90; Ivan *et al.* 2014, entire).

Lynx prey opportunistically on other small mammals and birds, especially red squirrels, grouse (*Bonasa umbellus*, *Dendragapus* spp., *Falcapennis canadensis*) and ptarmigan (*Lagopus* spp.), but alternate prey species do not sufficiently compensate for low availability of snowshoe hares, and lynx populations likely cannot persist over time in areas with consistently low hare densities (Brand *et al.* 1976, pp. 422–427; Brand and Keith 1979, pp. 833–834; Koehler 1990a, pp. 848–849; Mowat *et al.* 2000, pp. 267–268). Hares constitute the majority of the biomass in lynx diets even in areas with relatively low or marginal hare densities (Koehler and Aubry 1994, p. 85; Apps 2000, pp. 362-363; Aubry *et al.* 2000, pp. 375-378; Roth *et al.* 2007, pp. 2740-2741;

Squires and Ruggiero 2007, pp. 310-313; Hanson and Moen 2008, p. 9; Maletzke *et al.* 2008, pp. 1475-1477; Shenk 2009, pp. 13, 16). This remains true in years when hare abundance is low and proportionally more alternate prey items are taken (Brand *et al.* 1976, pp. 424-427; O'Donoghue *et al.* 1998, pp. 1198-1200; Ivan and Shenk 2016, p. 1053). Nonetheless, alternate prey, particularly red squirrels, may contribute to lynx persistence through cyclic hare population lows in the core of the range (O'Donoghue *et al.* 1997, pp. 156-160; 1998, pp.1204-1205) and may be important at the southern periphery of lynx range where hare numbers may be chronically marginal or low and where red squirrels may be less vulnerable than hares to projected impacts of continued climate warming (Roth *et al.* 2007, pp. 2740-2741; Peers *et al.* 2014, entire; Ivan and Shenk 2016, pp. 1050, 1054-1056).

Lynx typically mate in March and April, and kittens are born from late April to mid-June after a 60- to 70-day gestation period (Koehler and Aubry 1994, p. 81; Mowat *et al.* 2000, p. 285). Female lynx typically reach reproductive maturity in their second year (at 22 months of age); however, when hares are abundant, females may breed at 10 months of age and produce kittens as 1-year-olds (Koehler and Aubry 1994, p. 81; Mowat *et al.* 2000, p. 285). Males do not seem to breed as yearlings, and they do not contribute to rearing of young (ILBT 2013, p. 30). Lynx dens are typically located in areas of dense cover, where coarse woody debris, such as downed logs and windfalls, provides security and thermal cover for lynx kittens (McCord and Cardoza 1982, pp. 743-744; Koehler 1990a, pp. 847-849; Slough 1999, p. 607; Squires and Laurion 2000, pp. 346-347; Organ *et al.* 2008, entire; Squires *et al.* 2008, pp. 1497, 1501-1505; Moen and Burdett 2009, pp. 5-8). Dens have been documented in both mature and younger boreal forest stands (Mowat *et al.* 2000, pp. 274-275; Squires *et al.* 2008, p. 1497; ILBT 2013, pp. 29-30; 78 FR 59441-59442; 79 FR 54809-54810; Organ *et al.* 2008, entire), and the amount of structure (e.g., downed trees; large, woody debris; tip-up mounds) seems to be more important than the age of the forest stand for lynx denning habitat (Mowat *et al.* 2000, pp. 274-275, Organ *et al.* 2008, p. 1516; Moen and Burdett 2009, p. 5). Denning habitat is not thought to be a limiting factor for lynx in the DPS (Moen *et al.* 2008a, p. 1512; Organ *et al.* 2008, pp. 1514, 1516–1517; Squires *et al.* 2008, p. 1505; ILBT 2013, p. 30; 79 FR 54790). Dens must be near foraging habitat to allow females to adequately provision dependent kittens, and females seem to select den sites near prey sources to minimize time spent away from kittens while foraging (Moen *et al.* 2008a, p. 1507; Vashon *et al.* 2012, p. 16; ILBT 2013, p. 29). Females attend kittens at the natal den site and 1 or more (up to 5) alternate or maternal dens until kittens are about 6-10 weeks old (Squires *et al.* 2008, p. 1502; Olson *et al.* 2011, pp. 458-460; Vashon *et al.* 2012, p. 17; ILBT 2013, p. 29).

Thereafter, kittens remain with their mothers through their first winter, apparently learning from her how to hunt and capture prey, initially on a small portion of her home range, but by fall on the larger area the female used before kittens were born (Mowat *et al.* 2000, pp. 269, 278). Juveniles remain closely associated with their mothers until February or March, when family groups begin to break up, with young typically dispersing in April and May (Mowat *et al.* 2000, pp. 278-279) to establish their own home ranges. Female offspring may establish home ranges overlapping or adjacent to their mother's home range and maintain mother-daughter bonds throughout their lives (Mowat *et al.* 2000, pp. 279-280). Male home ranges may slightly overlap

adjacent male home ranges. While male home ranges typically overlap 1 to 3 female home ranges, and female home ranges are partially or completely encompassed by a male's home range, core areas within home ranges appear to be exclusive except during the breeding season (Koehler and Aubry 1994, pp. 90-91; Mowat *et al.* 2000, pp. 276-280; Vashon *et al.* 2012, pp. 17, 22-23). Fidelity to home ranges over several years has been documented for both sexes, but shifts and abandonment of home ranges have also been documented (Koehler and Aubry 1994, p. 91; Mowat *et al.* 2000, p. 277). Lynx have been documented to live up to 16 years in the wild (Kolbe and Squires 2006, entire).

Lynx populations in Canada fluctuate in response to the cycling of hare populations (Elton and Nicholson 1942, pp. 241–243; Hodges 2000b, pp. 118–123; Mowat *et al.* 2000, pp. 265–272), with synchronous fluctuations in lynx numbers emanating from the core of the Canadian population and spreading over vast areas, generally lagging hare numbers by 1 year (McKelvey *et al.* 2000a, pp. 232, 239; Mowat *et al.* 2000, pp. 266, 270). When hares are abundant, lynx have higher pregnancy rates and larger litter sizes, higher kitten survival, and lower adult mortality, resulting in rapid population growth during the increase phase of the hare cycle (Slough and Mowat 1996, pp. 955–956; Mowat *et al.* 2000, pp. 266, 270–272, 281–289). When hare populations are low, female lynx produce few or no kittens that survive to independence (Nellis *et al.* 1972, pp. 326–328; Brand *et al.* 1976, pp. 420, 427; Brand and Keith 1979, pp. 837–838, 847; Poole 1994, pp. 612–616; Slough and Mowat 1996, pp. 953–958; O'Donoghue *et al.* 1997, pp. 158–159; Aubry *et al.* 2000, pp. 388–389; Mowat *et al.* 2000, pp. 285–287). When hares decline, lynx mortality rates increase, largely because of starvation, and home range sizes and dispersal/emigration rates also increase (Ward and Krebs 1985, pp. 2821–2823; O'Donoghue *et al.* 1997, pp. 156, 159; Poole 1997, pp. 499–503; Mowat *et al.* 2000, pp. 265–272, 278, 281–294). Lynx numbers decline dramatically during the “crash” phase of the hare cycle (Slough and Mowat 1996, p. 956; Mowat *et al.* 2000, pp. 283-285), when many lynx starve and many others abandon home ranges and disperse in search of food, with many dispersers also dying, often soon after initiating dispersal (Mowat *et al.* 2000, p. 293).

In Canada, lynx abundance may be 3 to 17 times higher at the peak versus the low of the hare cycle, with lynx densities reaching 30-45/100 km² (78-117/100 mi²) in optimal dense regenerating forests 15-40 years post-fire, 8-20/100 km² (21-52/100 mi²) in older forests or further south, and < 3/100 km² (< 8/100 mi²) at the hare cycle low (Slough and Mowat 1996, pp. 952, 955; Mowat *et al.* 2000, p. 283; Hatler and Beal 2003, pp. 2, 5; Environment Canada 2014, p. 1). In southern Canada, where hares are less abundant and hare population cycles are muted or absent, lynx populations may be stable at 2-3/100 km² (5-8/100 mi²; Environment Canada 2014, p. 1). Lynx densities estimated in the contiguous United States have ranged from 9.2-13/100 km² (24-34/100 mi²), including kittens, in Maine's highest-quality habitat when hares were abundant (Vashon *et al.* 2008a, pp. 1483-1484; Vashon *et al.* 2012, pp. 14-15) to 2.3/100 km² (6/100 mi²) in Washington when hare abundance was low (Koehler 1990a, pp. 847-850).

Correspondingly, hare abundance may also influence lynx home range size. Ward and Krebs (1985, pp. 2819-2820) documented a 3-fold increase in home range size in southwestern Yukon, from 13 km² (5 mi²) on average when hares were abundant and increasing to 39 km² (15

mi²) when hare density was low (90 percent MCP method). Poole (1994, pp. 613-614) documented a similar trend in the Northwest Territories, where lynx home range size increased from 17 km² (7 mi²; males and females combined) when hares were abundant, to 44 km² (17 mi²) and 62 km² (24 mi²) for males and females, respectively, when hare numbers declined (95 percent MCP method). In contrast, Breitenmoser *et al.* (1993, p. 552) reported no change in lynx home range size despite a 10-15 fold increase in lynx density as hare abundance increased in the southern Yukon (home range estimation method not provided). Similarly, in Maine, lynx home range size did not increase when hare densities in the best habitats declined by half from 2 hares/ha (0.8 hares/ac) to 1 hare/ha (0.4 hares/ac; Mallett 2014, pp. 53-93; 90 percent fixed kernel method). In general, hare and lynx densities are lower and lynx home ranges larger at the southern periphery of the lynx's range, including most of the DPS range, and lynx densities are similar to those of northern populations during the low phase of the hare population cycle (Koehler and Aubry 1994, p. 93; Aubry *et al.* 2000, pp 382-385; Apps 2000, pp. 362-367; Burdett *et al.* 2007, pp. 463-465).

Although empirical data are lacking and would be difficult to acquire (ILBT 2013, p. 82), the lynx's physical adaptations (described above) are thought to provide lynx a seasonal advantage over potential terrestrial competitors and predators, which generally have higher foot-loading, causing them to sink into the snow more than lynx (McCord and Cardoza 1982, p. 748; Murray and Boutin 1991, entire; Buskirk *et al.* 2000a, pp. 86-95; Ruediger *et al.* 2000, pp. 1-11; Ruggiero *et al.* 2000b, pp. 445, 450). Buskirk *et al.* (2000a, entire) described potential exploitation (for food) and interference (avoidance) competition between lynx and several other terrestrial and avian predators of hares, several of which have also been documented to prey on lynx. Documented lynx predators include cougar (*Puma concolor*, also mountain lion), coyote (*Canis latrans*), wolverine (*Gulo gulo*), gray wolf (*Canis lupus*), fisher (*Pekania pennant*), and other lynx (ILBT 2013, pp. 33, 35). Bobcats are also likely capable of killing lynx in some circumstances. Although lynx have co-evolved with other predators, the influence of predation on lynx populations is unknown (ILBT 2013, pp. 35-36). Coyotes are now more widespread and abundant in the southern periphery of the lynx distribution than they were historically (Gompper 2002, entire), while cougars have been extirpated from the eastern half of the United States (except Florida; USFWS 2011a, entire) but are more abundant and widespread in the western United States now than in the mid-1900s (Buskirk *et al.* 2000a, p. 89).

The species above, along with red fox (*Vulpes vulpes*), American marten (*Martes americana*), mink (*Mustela vison*), as well as a suite of avian predators (e.g., northern goshawk [*Accipiter gentilis*], northern hawk-owl [*Surnia ulula*], great gray owl [*Strix nebulosus*], and great-horned owl [*Bubo virginianus*]) may compete with lynx for hares (Buskirk *et al.* 2000a, pp. 86-95; ILBT 2013, p. 16). Of these, coyotes are the most likely to exert local or regionally important exploitation competition impacts to lynx, and coyotes, bobcats, and cougars are capable of imparting interference competition effects on lynx (Buskirk *et al.* 2000a, p. 89). Interference would be most likely during summer but also during winter in areas lacking deep, unconsolidated snow (ILBT 2013, p. 36). Except for fisher and marten, lynx predators and potential terrestrial competitors all have higher foot-loading, making them less efficient at traveling and hunting in the snow conditions favorable for lynx (Murray and Boutin 1991, entire; Buskirk *et al.* 2000a, pp 86-95;

Krohn *et al.* 2005, entire) and, therefore, likely limiting, at least seasonally, interactions between lynx and these species. The fisher has foot-loading similar to lynx, and the marten's is even lower (Buskirk *et al.* 2000a, p. 90), but both species have much shorter legs, which likely limits their mobility in deep, unconsolidated snow compared to lynx. The extent to which predation and competition may influence lynx populations in the DPS remains uncertain.

Lynx populations in the contiguous United States seem to function as subpopulations or southern extensions of larger populations in southern and eastern Canada (McKelvey *et al.* 2000b, pp. 21, 25, 33; 65 FR 16052–16082; 68 FR 40077–40099; 71 FR 66025–66035; 74 FR 8616–8641; Koen *et al.* 2015, pp. 527-528). Populations in the DPS are relatively isolated from one another, though most are directly connected via dispersal to lynx populations in Canada (McKelvey *et al.* 2000b, pp. 25-34; U.S Fish and Wildlife Service 2005, p. 2). DPS populations are at the periphery of the species' range and some, particularly in the West (geographic units 3-6), may behave as islands in a mainland-island metapopulation construct. In such a system, larger islands with higher habitat quality and in closer proximity to the mainland would be more likely to support persistent resident populations and to sometimes act as “sources” that produce surplus animals that may disperse to other islands. Smaller islands with lower habitat quality or at greater distance from the mainland may, in contrast, act as “sinks” that depend on immigration from source populations (McKelvey *et al.* 2000b, p. 30), and which may support resident lynx only occasionally, intermittently, or temporarily.

Although lynx habitats are more contiguous in units 1 and 2 than in the western units, and units 1 and 2 are connected to larger contiguous habitats and lynx populations in Canada, they remain peripheral populations, and a metapopulation structure in which they receive intermittent immigration from the larger population may still exist, even if the mainland-island construct does not apply. Lynx disperse in both directions across the Canada–United States border (Aubry *et al.* 2000, pp. 386-387; Moen *et al.* 2010b, pp. ii, 17, 19; Vashon *et al.* 2012, p. 22), and this connectivity and interchange with lynx populations in Canada is thought to be important to the conservation of lynx populations in the DPS. (McKelvey *et al.* 2000b, p. 33; Schwartz *et al.* 2002, p. 522; U.S Fish and Wildlife Service 2005, p. 2; ILBT 2013, p. 34, 42, 47, 54, 60, 65; Squires *et al.* 2013, p. 187). However, it remains uncertain whether the demographic and genetic health and persistence of populations in the DPS depend on regular or intermittent immigration of lynx from Canada and if so to what extent (McKelvey *et al.* 2000a, pp. 241-242; 79 FR 54793).

2.2.1 Ecological Requirements of Individuals

From birth through recruitment of at least one of its progeny into the breeding population, the ecological requirements of an individual lynx are met if:

- 1) its mother occupies a home range containing
 - a) secure denning habitat,
 - b) adequate prey abundance (especially snowshoe hares) to support lactation during the early kitten stage and later provisioning of the kitten with meat,

- c) habitat (boreal forest and snow) conditions that reduce the likelihood and effect of competition from other hare predators, and
 - d) a low likelihood of encounters with lynx mortality agents (predators, traps, vehicles, etc.);
- 2) its mother's home range occurs within a larger landscape that also contains adequate hare abundance and available habitat into which the yearling lynx may disperse and establish its own home range after the period of maternal dependence, with low likelihood of adverse competition or mortality; and
 - 3) the larger landscape also supports other secure lynx home ranges and ensures the opportunity to encounter a lynx of the opposite sex, breed successfully, and contribute to the recruitment of at least 1 offspring into the breeding population during its lifetime.

In cyclic lynx populations in the core of the species' range (northern Canada and Alaska), there is a strong element of timing that determines whether these individual needs will be met. During the decline and low phases of the hare population cycle, few or no kittens are born, very few survive until their first winter, and recruitment may collapse completely or nearly so for several successive years (Slough and Mowat 1996, entire; Mowat *et al.* 2000, pp. 266, 285-287). Therefore, even in the core of the species' range, a kitten born during a period of declining or low hare abundance is very unlikely to survive to independence, breed successfully, and replace itself within the breeding population in its lifetime. Conversely, a kitten born during the increase or high phase of the hare population cycle is much more likely to survive and, therefore, have an opportunity to breed successfully and replace itself via recruitment of 1 or more of its offspring into the breeding population.

At the southern periphery of the lynx's range (southern Canada and the contiguous United States), hare population cycles are of lower amplitude or absent (Hodges 2000a, pp. 163–173; Hodges *et al.* 2009, pp. 870, 875–876; Scott 2009, pp. 1–44; Environment Canada 2014, p. 1; Hodges *in* Lynx SSA Team 2016a, pp. 16-17), hare densities are typically on the lower end of densities reported for northern populations, and lynx abundances and demographic rates in the south are typically like those of northern lynx populations during hare lows (Koehler and Aubry 1994, p. 93; Aubry *et al.* 2000, pp 382-385; Apps 2000, pp. 362-367). Therefore, in southern populations the likelihood is probably relatively low that an individual lynx will have its ecological requirements met sufficiently to replace itself in the breeding population. Also in the south, there are more diverse assemblages of potential competitors and predators, more natural patchiness and anthropogenic fragmentation of lynx habitat (fewer areas with adequate hare densities and favorable snow conditions distributed broadly across large landscapes), and higher road densities and, thus, greater potential for lynx-vehicle collisions (Wolff 1980, p. 128; Buskirk *et al.* 2000a, entire). These factors probably further reduce the likelihood that an individual lynx in the southern periphery of the range will survive, reproduce successfully, and have 1 or more offspring recruited into the resident breeding population.

Individual lynx require large areas (tens to hundreds of square kilometers) of boreal forest landscapes to support their home ranges, provide hares in adequate abundance to meet their

nutritional needs, provide breeding opportunities, and facilitate dispersal and exploratory travel. Female home ranges must also provide secure denning habitat in close proximity to foraging areas with high hare densities to allow females to adequately provide for dependent kittens (Moen *et al.* 2008a, p. 1507; Vashon *et al.* 2012, p. 16; ILBT 2013, p. 29). The size of lynx home ranges is strongly influenced by the quality of the habitat, particularly the abundance of snowshoe hares, in addition to other factors such as gender, age, season, and density of the lynx population (Aubry *et al.* 2000, pp. 382–385; Mowat *et al.* 2000, pp. 276–280). Generally, females with kittens have the smallest home ranges, likely related to their need to stay close to dens and dependent kittens, and males have the largest home ranges (Moen *et al.* 2005, p. 11; Burdett *et al.* 2007, p. 463; ILBT 2013, p. 24).

The increased natural patchiness and fragmentation of high-quality hare habitat where boreal forest conditions transition to temperate forest types require individual lynx in many parts of the DPS to maintain relatively large home ranges that include patches of higher hare densities within a matrix of lower-quality habitats with lower hare densities (ILBT 2013, p. 126; 78 FR 59434; also see 2.3.3). Larger home ranges likely require more energy output associated with greater foraging effort (Apps 2000, p. 364) and possibly increased exposure to predation and other mortality factors than lynx face in the core of their range (78 FR 59438). Annual home range sizes reported for lynx in the contiguous United States (table 3) vary greatly across the DPS but are generally larger in the west than the east; however, differences should be interpreted with caution because different methods, sample sizes, and estimators were used to generate them (ILBT 2013, pp. 23-24; also see footnotes to table 3, below).

Table 3. Reported annual home range sizes for Canada lynx in the contiguous United States.

Geographic Unit	Mean or Median Annual Lynx Home Range Size km ² (Range)		References (Page Nos.)
	Female	Male	
N Maine	25-33 (14-70)	39-60 (24-102)	Vashon <i>et al.</i> 2008a (1482) ¹ ; Mallett 2014 (169) ²
NE Minnesota	17-87 (13-122)	160-267 (86-439)	Mech 1980 (263-265) ³ ; Burdett <i>et al.</i> 2007 (460-463) ⁴ ; Moen <i>et al.</i> 2008b (17) ⁴
NW Montana/ NE Idaho	43-90 (11-157)	122-220 (29-552)	Brainerd 1985 (20) ⁵ ; Squires and Laurion 2000 (343-344) ³ ; Squires <i>et al.</i> 2004a (13, table 6) ⁶
N-C Washington	37-91 (37-91)	49-69 (29-99)	Brittill <i>et al.</i> 1989 <i>in</i> Stinson 2001 (5) ⁷ ; Koehler 1990a (847) ⁷ ; Maletzke <i>in</i> Lynx SSA Team 2016a (21) ⁷
GYA	50-105 (32-105)	116-824 (98-2,181)	Squires and Laurion 2000 (343-344) ³ ; Squires <i>et al.</i> 2003 (12-13) ⁶
W Colorado	75-704 (NA)	103-387 (NA)	Shenk 2008 (10) ²

¹85% fixed kernel; ²90% fixed kernel; ³95% minimum convex polygon (MCP); ⁴95% MCP and 95% fixed kernel; ⁵Minimum area method; ⁶95% fixed kernel; ⁷100% MCP.

Juvenile and adult lynx require about 400 and 600 grams (14 and 21 ounces) of food per day (for adults, 0.4-0.5 hares/day, 170-200 hares/year), respectively, to meet their basic nutritional requirements (Saunders 1963, p. 390; Nellis *et al.* 1972, pp. 324-325). Several sources (Ruggiero *et al.* 2000b, pp. 446-447; ILBT 2013, pp. 26, 125) have suggested that landscape-level hare densities ≥ 0.5 hares/ha (0.2 hares/ac) are necessary to support lynx home ranges and resident breeding populations. Lynx home range abandonment, dispersal, and mortality increase when hare densities are lower, and lynx may be unable to survive where landscape hare densities are below 0.3 hares/ha (0.12 hares/ac; Ward and Krebs 1985, pp. 2819-2822; Slough and Mowat 1996, entire). Recent research in the contiguous United States generally supports the 0.5 hares/ha threshold. For example, in northern Maine, areas with average landscape hare densities of 0.74 hares/ha (0.30 hares/ac) supported resident breeding lynx, but areas with hare densities below 0.5 hares/ha (0.2 hares/ac) were not occupied by lynx (Simons-Legaard *et al.* 2013, pp. 567, 574-575). In northeastern Minnesota, resident lynx maintained home ranges where landscape hare densities were 0.64 hares/ha (0.26 hares/ac), but nearby Voyageurs National Park, where hare density was estimated at 0.35 hares/ha (0.14 hares/ac), did not support resident breeding lynx (Moen *et al.* 2012, pp. 352-354). Similarly, in western Montana, resident lynx used dense young forest stands with mean summer and winter hare densities of 0.64 hares/ha (0.26 hares/ac) and 0.47 hares/ha (0.19 hares/ac), respectively, and dense mature multi-story stands in winter when mean hare density was 0.53 hares/ha (0.21 hares/ac), but they did not use more open young or mature stands where hare densities ranged from 0.12 - 0.20 hares/ha (0.05 - 0.08 hares/ac; Squires and Ruggiero 2007, pp. 313-314).

Steury and Murray (2004, p. 137) suggested minimum hare densities of 1.1 - 1.8 hares/ha (0.45 - 0.73 hares/ac) would be necessary to support lynx reintroduction efforts in the southern portion of the range, but Murray *et al.* 2008 (p. 1468) acknowledged that threshold could be overly conservative if southern lynx are less reliant on hares (i.e., more reliant on alternate prey) or if southern hare numbers are more stationary so that resident lynx numbers in the south do not fluctuate as dramatically as is typical in northern populations. Indeed, more than 10 years after translocations of Canadian and Alaskan lynx ceased, resident lynx continue to occupy parts of western Colorado, where hare densities are generally much lower, and lynx there rely heavily on red squirrels, which accounted for 23 ± 6 percent (annual range = 0.1 to 66 percent) of prey items identified over 11 winters (Shenk 2009, pp. 16, 24).

In addition to adequate hare density, individual lynx require landscapes in which they are unlikely to encounter animals that may prey on them or suffer reduced fitness from competition with other hare predators. As described above, the lynx has a much lower foot-loading than most of its potential predators and competitors, and this is believed to provide an advantage in places that receive deep and persistent unconsolidated snow. Although specific snow requirements for lynx (amount/depth, quality, persistence) have not been quantified throughout the DPS range, historical lynx occurrence records in the contiguous United States were correlated with areas that received at least 4 months (December through March) of continuous snow coverage (Gonzalez *et al.* 2007, p. 7). Where snow conditions do not consistently favor

lynx, increased potential for predation and competition would be expected (Peers *et al.* 2013, p. 8). Finally, individual lynx are more likely to survive, breed, and replace themselves in the breeding population if they occupy home ranges where trapping is prohibited or trapping pressure is low (Slough and Mowat 1996, entire), high-speed/high-volume roadways are absent (ILBT 2013, pp. 77-78), and other potential anthropogenic causes of lynx mortality are absent or minimal.

In summary, individual lynx require large landscapes with hare densities that maximize their chances of (1) surviving to independence, (2) establishing and maintaining a home range, (3) breeding successfully, and (4) contributing genes to future generations (Breitenmoser *et al.* 1993, p. 552). These landscapes also must provide conditions that allow lynx to compete sufficiently for hares and minimize the likelihood of predation and other sources of lynx mortality. The available science, including recent research in the DPS range, suggests that landscape-level hare densities consistently ≥ 0.5 hares/ha (0.2 hares/ac) and favorable snow depth and conditions for about 4 months are needed to support lynx occupancy, reproduction, and recruitment. At the southern periphery of lynx distribution, some places, including within the range of the DPS, seem to be at minimum thresholds to meet these requirements or do so inconsistently.

2.2.2 Ecological Requirements of Populations and the DPS

Lynx populations require essentially the same things that individual lynx do, but on a larger landscape with hare densities and habitat conditions capable of consistently supporting multiple home ranges, breeding and dispersal opportunities, and reproductive and survival rates such that recruitment and immigration will, on average over the long term, equal or exceed mortality and emigration (Pulliam 1988, pp. 652-654). To support persistent lynx populations, such landscapes must provide for the survival of at least some resident lynx even when hares are least abundant and/or other habitat features (e.g., snow conditions) are least favorable so that the lynx population can recover, perhaps aided by immigration, when hare numbers and/or other habitat conditions improve. As with individual lynx, populations are more likely to persist in landscapes where the effects of competition, predation, and human-caused mortality (e.g., trapping, vehicle collisions) are relatively lower.

In a metapopulation structure like that thought to govern lynx population dynamics, the persistence of peripheral populations is determined by colonization and extinction rates (McKelvey *et al.* 2000b, p. 25). Colonization is driven by the number of populations, the distances between them, and the species' dispersal capabilities and timing. Extinction rates are determined by population size and demographic and environmental stochasticity, with extinction more likely in smaller and more isolated populations (McKelvey *et al.* 2000b, pp. 25-31). Formal population viability analyses (PVAs) have not been published for most lynx populations in the DPS and may not be possible for some populations given limited data and natural temporal variation in demographic rates (McKelvey *et al.* 2000b, pp. 22, 30). Although some demographic data are available for most lynx populations in the DPS, most are limited to relatively few, small study areas or relatively short durations. There remains uncertainty about whether, and if so to

what extent, the demographic health of DPS populations relies on immigration from northern (Canadian) populations; and immigration rates are not known for DPS populations (McKelvey *et al.* 2000b, pp. 24-34). These factors likely preclude development of meaningful DPS-wide or unit-specific empirical population viability models (McKelvey *et al.* 2000b, p. 22).

In the core of the species' range in the southern Yukon, Slough and Mowat (1996, p. 952, table 4) calculated a lynx population growth rate (λ) = 2.03 (annual doubling) during the 4-year increase-to-peak phase of the hare cycle. This period of rapid growth was followed by a rate of λ = 1.01 (stable) during the first year of a hare decline, and λ = 0.10 and λ = 0.46 (rapid decline) during the first 2 years of the lynx population decline when hares were scarce. However, the natural range in λ that would be expected among peripheral, isolated, or semi-isolated lynx populations where hares are non-cyclic or weakly-cyclic (i.e., in DPS and some southern Canadian populations; Murray 2000, pp. 1210-1215; Murray 2003, pp 152-155), versus those that would signal long-term population decline or instability is unknown. Despite this, and the limitations noted above, Squires (*unpubl. data in Lynx SSA Team 2016a*, p. 20) calculated population growth rates in northwestern Montana of λ = 0.92 for lynx in the Seeley Lake area (i.e., declining population trend, 1999-2007) and λ = 1.16 for lynx in the Purcell Mountains (increasing trend, 2003-2007). Likewise, MDIFW in 2012 calculated an intrinsic rate of growth of 0.05 (λ = 1.05) for Maine's lynx population based on demographic data from a radiotelemetry study collected over a 12-year period (Vashon *et al.* 2012, Appendix VI). Neither the Montana nor Maine estimates incorporated rates of immigration/emigration (i.e., both assumed immigration and emigration rates of zero, which is very unlikely and contradicted by historical and recent evidence of lynx dispersal in both directions across the Canada-United States border across the DPS range). Schwartz (2017, p. 4) noted that very low immigration rates (less than 1 female/year on average for a theoretical population of 100 lynx) could provide population stability or even growth, suggesting that the Seeley Lake population and perhaps other DPS populations are probably being bolstered by low levels of immigration, which may go undetected. Other efforts to model lynx population dynamics in the DPS range include those of Lyons *et al.* (2016, entire), who developed spatially-explicit, individual-based population models to estimate reductions in potential lynx carrying capacity in Washington associated with recent large wildfires, and Licht *et al.* (2017, *in press*, entire), who conducted a PVA of a potential lynx reintroduction to Isle Royale in Lake Superior, about 22 km (14 mi) east of Unit 2.

Although minimum viable population sizes have not been derived for lynx populations in the DPS, the Service's Recovery Outline (USFWS 2005, p. 5) suggested landscapes of at least 1,250 km² (483 mi²) with sufficient boreal/subalpine habitat, hare densities, and snow conditions favorable for lynx. These are the minimum landscape size and habitat conditions thought necessary to support a minimum lynx population of at least 25 adults based on a density of 1 lynx per 50 km² (USFWS 2005, p. 5). McKelvey *et al.* (2000b, p. 29) noted that extinction (extirpation) risk should decrease with increasing population size, and that extinction resulting from demographic stochasticity is very unlikely even for a population (generally; not specific to lynx) with as few as 20 reproducing females. Kramer-Schadt *et al.* (2005, entire) developed a spatially explicit population model for Eurasian lynx in Germany which they combined with demographic scenarios to evaluate the likely success of potential reintroduction efforts; they

concluded that at least 10 females and 5 males would be required to establish a population with an extinction probability less than 5 percent over 50 years. Rodriguez and Delibes (2003, entire) evaluated extinction among populations of Iberian lynx; they found that extinction occurred only in small populations that occupied habitats of less than 500 km² and that extinction within 35 years was unlikely among populations occupying areas of at least 500 km² of adequate habitat quality.

In summary, lynx populations need large (thousands of square kilometers) boreal forest landscapes with hare densities capable of supporting (1) multiple lynx home ranges, (2) reproduction and recruitment most years, and (3) at least some survival even during years when hare numbers are low. These landscapes also must have snow conditions (consistency, depth, and duration) that allow lynx to outcompete other terrestrial hare predators. To persist, lynx populations must exhibit recruitment and immigration rates that exceed mortality and emigration rates on average over the long-term. Immigration may be particularly important to the persistence and stability of lynx populations at the southern periphery of the range, including those within the DPS, where hare densities are generally low and hare populations are either non-cyclic or weakly-cyclic compared to northern populations. Low hare densities reduce the likelihood that lynx recruitment will consistently equal or exceed mortality, and non-cyclic or weakly-cyclic hare populations are unlikely to allow the rapid lynx population recovery observed in northern lynx populations when hare numbers increase dramatically after cyclic population crashes. Conversely, more stable hare populations, even at lower landscape-level densities, likely provide stability (i.e., prevent periodic steep declines) among lynx populations on the periphery of the range in the DPS and in southern Canada. Although immigration rates for DPS populations are unknown, as is the rate and periodicity of immigration needed to provide demographic stability among them, connectivity with and immigration from lynx populations in Canada are believed to be important to the persistence of lynx populations in the DPS (McKelvey *et al.* 2000a, pp. 232-242; 2000b, pp. 32-34; Schwartz *et al.* 2002, entire; USFWS 2005, p. 2; ILBT 2013, pp. 34, 42, 47, 54, 60, 65; Squires *et al.* 2013, p. 187; 79 FR 54789).

2.3 Historical and Current Lynx Distribution

2.3.1 Lynx Distribution and Status in Canada and Alaska

The Canada lynx is broadly distributed across northern North America from eastern Canada to Alaska (McCord and Cardoza 1982, p. 729; Poole 2003, p. 361; Vashon 2015, p. 4; Univ. of Alaska Center for Conservation Science 2016, p. 1). It is strongly associated with the expansive, continuous boreal forests of those areas, and its range largely overlaps that of its primary prey, the snowshoe hare, also a boreal forest specialist (Bittner and Rongstad 1982, p. 146; Mowat *et al.* 2000, pp. 268-269; Aubry *et al.* 2000, p. 375). In Canada, lynx are thought to occupy about 5.5 million km² (over 2.1 million mi²), which represents 95 percent of their historical range in that country (Environment Canada 2014, p. 2), and over 89 percent of the species' entire distribution. Nationally in Canada, lynx are classified as secure, widespread, and abundant; they are managed for long-term population stability, with a conservative estimate of 110,000

individuals during cyclic lows; and no acute, widespread threats to lynx have been identified (Environment Canada 2014, entire; Vashon 2015, pp. 1-6). Provincially, lynx status is considered secure in British Columbia, Manitoba, Ontario, Quebec, Newfoundland and Labrador, Northwest Territories, and the Yukon; sensitive in Alberta and Saskatchewan; at risk/endangered in New Brunswick and Nova Scotia; and undetermined in Nunavut (Environment Canada 2014, pp. 3-4; Vashon 2015, p. 1). Lynx were extirpated from Prince Edward Island (0.1 percent of lynx range in Canada) by the late 1800s, and on the mainland the southern margin of assumed lynx range has contracted northward in Quebec, southeastern Ontario, Manitoba, Saskatchewan, and Alberta (Poole 2003, p. 361; Bayne *et al.* 2008, pp. 1192-1195; Koen *et al.* 2014a, pp. 757-760).

In Alaska, lynx are distributed across roughly 534,454 km² (206,354 mi²) of boreal forest (Univ. of Alaska Center for Conservation Science, 2016, entire; Reimer 2016, *pers. comm.*), which represents about 8.7 percent of the species' breeding distribution. Lynx in Alaska are apparently secure, with low to moderate threats, and populations appear stable statewide, although total abundance is unknown (Alaska Natural Heritage Program 2008, pp. 2-4).

In both Alaska and Canada, lynx trapping is managed through regulated seasons and harvest levels, which are adjusted to avoid overexploitation, especially during the low phase of the lynx-hare population cycle (Alaska Natural Heritage Program 2008, pp. 2-6; Vashon 2015, pp. 5-6). Along the Canada-United States border in provinces adjacent to DPS lynx populations, lynx trapping is prohibited in New Brunswick (adjacent to northeastern Maine) but regulated trapping is permitted in Quebec (adjacent to northwestern Maine, northern New Hampshire, and northern Vermont), Ontario (adjacent to northeastern Minnesota), Alberta (adjacent to northwestern Montana), and British Columbia (adjacent to northwestern Montana, northern Idaho, and northern Washington). Because after 2 centuries of being legally harvested for the international fur trade it remains widespread and abundant over most of its range, and because managed harvest in recent decades does not appear to have caused significant range loss or population decline, the lynx has been designated a "species of least concern" in accordance with the IUCN Red List of Threatened Species (Vashon 2015, entire).

2.3.2 Lynx Distribution in the Contiguous United States

2.3.2.1 Defining Lynx Distribution at the Periphery of the Range

Several aspects of lynx population dynamics and dispersal patterns have resulted in inconsistent approaches and difficulty in defining the range and/or distribution of the species, especially at the margins (74 FR 66942). There also is uncertainty and ambiguity in some historical lynx occurrence records, with early assessments based largely on trapping harvest records of questionable accuracy, particularly where lynx and bobcats overlap, and a reliance on anecdotal or unverified occurrence information (McKelvey *et al.* 2000a, pp. 208-210; 65 FR 16054). These issues confound efforts to accurately portray the species' historical distribution in the contiguous United States and to assess the current distribution relative to historical conditions (McKelvey *et al.* 2008, pp. 553-554; 79 FR 54814-54815; McKelvey *in* Lynx SSA

Team 2016a, p.11). This has resulted in inaccurate portrayals of lynx distribution and misperceptions that the historical range of lynx in the contiguous United States was once much more extensive than is ecologically possible (68 FR 40080; 74 FR 66942).

The boreal forest reaches its southern extent in the northern contiguous United States and it becomes naturally patchy and marginal for hares and lynx in places where it transitions to temperate forest types. Many areas of boreal or boreal-like (spruce-fir) forest (e.g., the Appalachian Mountains from New York southward in the East, most of northern Michigan and northern Wisconsin in the Midwest, and the Southern Rocky Mountains and Southern Cascade Mountains in the West) probably never supported persistent native lynx populations despite the presence of snowshoe hares. Hare densities in these areas are generally low and appear insufficient to support resident lynx populations over time. Only a relatively few areas in the contiguous United States historically supported an adequate quantity, quality, and spatial arrangement of habitat to support resident lynx populations continuously over time, and many historical lynx occurrences across a large area of the contiguous United States were likely dispersers. The occurrence of dispersing lynx is unpredictable, and dispersing lynx will probably continue to move periodically and temporarily into areas that cannot support persistent populations (68 FR 40077).

Because the lynx is highly mobile and has, throughout most of its range, cyclic population dynamics that are closely tied to cyclic snowshoe hare populations, numbers of lynx naturally fluctuate and become extremely low during lows in decadal hare cycles. The dramatic, cyclic fluctuations in lynx populations across much of the range as they track cyclic hare populations and the mass synchronous dispersals (irruptions) of large numbers of lynx into the contiguous United States when northern hare populations crashed are well-documented (Elton and Nicholson 1942, entire; Gunderson 1978, entire; Thiel 1987, entire; McKelvey *et al.* 2000a, pp. 219, 232-242; Mowat *et al.* 2000, pp. 281-294; ILBT 2013, p. 33). These events have resulted in records of lynx occurrence, in some cases very rarely, in other cases sometimes in large numbers and with intermittent (cyclic) regularity, in places that otherwise lack evidence of persistent lynx presence or the habitats and hare densities necessary to support a resident lynx population (USFWS 2005, pp. 3-4; 79 FR 54787-54789, 54793-54795, 54812-54823).

Many records of lynx in the contiguous United States appear to be related to such events, including the unprecedented “explosions” of lynx observed in the early 1960s and 1970s (Gunderson 1978, entire; McKelvey *et al.* 2000a, pp. 232-242). During these events, many lynx occurred in anomalous habitats, exhibited unusual behavior, suffered high mortality, and numbers declined dramatically within a few years of irruptive peaks (Gunderson 1978, entire; Thiel 1987, entire; McKelvey *et al.* 2000a, p. 242). Because dispersing lynx typically do not persist in these areas of temporary range expansion, disappearing fairly quickly after irruptions, van Zyll de Jong (1971, p. 16) suggested that only areas that support lynx populations throughout both the low and the high phases of the “10-year cycle” (i.e., across the natural range of hare densities) should be considered to constitute the species’ range. In its 2003 remanded determination, the Service determined that lynx in the contiguous United States exist either as resident populations or as dispersers, that dispersing lynx are often found repeatedly

and for variable amounts of time in habitats that cannot sustain breeding populations over time (though some breeding may occur occasionally in some of these areas), and that such areas probably contribute little (if at all) to the persistence of lynx in the DPS (68 FR 40077, 40079-80). This repeated dispersal into habitats that ultimately cannot support the species (“sink” habitats) often leads to confusion about where lynx populations may be viable (74 FR 66938).

The metapopulation structure thought to govern lynx populations in the DPS (McKelvey *et al.* 2000b, pp. 25-31; see Section 2.2) and the transitional (and, therefore, increasingly fragmented and isolated) and spatially- and temporally-shifting nature of lynx habitat at the southern periphery of the range (Koehler and Aubry 1994, pp. 78-79; McKelvey *et al.* 2000b, pp. 29-30; 74 FR 66940; 79 FR 54814) also present challenges in defining the distribution of lynx. Both factors suggest that some areas may naturally support resident lynx only temporarily or occasionally when habitat conditions (both boreal forest vegetation supporting abundant hares and snow conditions favoring lynx) are adequate and/or when immigration is sufficient to offset the lower productivity and recruitment rates expected among lynx populations in marginal or suboptimal habitats. McKelvey *et al.* (2000b, pp. 21, 29-31) described such habitats as “... source-sink mosaics that shift with disturbance and succession,” and the contribution, if any, of these places (especially those that act more often as “sinks” than “sources”) to the maintenance and persistence of lynx populations in the DPS remains questionable (74 FR 66938).

Finally, the southern periphery of the lynx’s range, where lynx are rare in many places, overlaps with the northern distribution of the much more common bobcat (Peers *et al.* 2012, pp. 4-5). The 2 species are difficult to distinguish in the field, they often were not reliably differentiated in historical trapping records (McKelvey *et al.* 2000a, pp. 208-209), and errors in early accounts of lynx distribution based on anecdotal information seem likely (Halfpenny and Miller 1980, pp. 1, 3-8; Meaney 2002, pp. 3-5, Hoving *et al.* 2003, pp. 366-367). Because of the large effect that relatively few errors in identification can have on assessments of the distribution of rare animals, McKelvey *et al.* (2000a, p. 209; 2008, pp. 553-554) suggest that anecdotal information should be interpreted with caution, and only verified occurrence data should be used to assess historical and current lynx distributions.

These complexities of lynx population dynamics and our incomplete understanding of the limited lynx occurrence data, combined with a naturally dynamic and transitional habitat, make it difficult, if not impossible, to precisely delineate the historical or current distribution of resident lynx populations in the contiguous United States (Koehler and Aubry 1994, p. 79; 68 FR 40084). While recognizing these limitations, we use our best professional judgment of the best scientific and commercial data available to make conclusions about the range of the lynx for the purposes of this SSA. In the following section, we describe the types and distributions of potential lynx habitats in the contiguous United States, and our current understanding of the historical and current distributions of resident lynx populations in the DPS considering the factors discussed above.

2.3.2.2 Lynx Distribution within the DPS Range

The southern periphery of boreal forest vegetation extends into parts of the northern contiguous United States, where it transitions to the Acadian forest in the Northeast (Seymour and Hunter 1992, pp. 1, 3), deciduous temperate forest in the Great Lakes region, and subalpine forest in the Rocky Mountains and Cascade Mountains in the west (Agee 2000, pp. 40-41). In much of the DPS range, these boreal forest landscapes become naturally patchy and transitional because they are at the southern edge of the boreal forest range, and they are limited, particularly in the west, by elevation and/or aspect (Ruediger *et al.* 2000, p. 4-16; 68 FR 40090). Non-forested land uses (e.g., agriculture, development) become increasingly prevalent in these areas. These factors generally limit snowshoe hare populations in the contiguous United States from achieving landscape densities similar to those of the expansive northern boreal forest in Alaska and Canada, where hares are generally more evenly distributed across the landscape and more abundant except during cyclic population lows (Wolff 1980, pp. 123-128; Buehler and Keith 1982, pp. 24, 28; Koehler 1990a, p. 849; Koehler and Aubry 1994, p. 84; Aubry *et al.* 2000, pp. 373-375, 382, 394). Consequently, important foraging habitat for lynx is often more limited and fragmented in the contiguous United States than in boreal forests of northern Canada and Alaska (Berg and Inman 2010, p. 6), and overall habitat quality is typically lower.

The habitats that lynx use in the contiguous United States are characterized by patchily-distributed moist forest types with relatively higher hare densities in a matrix of other habitats (e.g., hardwoods, dry forest, non-forest) with lower landscape hare densities (ILBT 2013, p.126; 78 FR 59434). In these areas, lynx incorporate the matrix habitat (non-boreal forest habitat elements) into their home ranges and use it for traveling between patches of boreal forest that support higher hare densities where most lynx foraging occurs. In some areas, patches of habitat containing snowshoe hares become so small and fragmented that the landscape cannot support lynx home ranges (ILBT 2013, p. 77) or populations over time (68 FR 40077). Additionally, the presence of more snowshoe hare predators and potential lynx competitors at southern latitudes may inhibit the potential for high-density hare populations (Wolff 1980, p. 128). Wirsing *et al.* (2002, entire) concluded that high predation rates on hares in fragmented habitats may explain the relative stability (i.e., lack of cyclicity) in southern hare populations. As a result, lynx in the DPS generally occur at relatively low densities compared to lynx in the core of the Canadian and Alaskan range when hares are abundant (Aubry *et al.* 2000, pp. 375, 393-394). Because the lynx is a habitat and prey specialist, its densities in the DPS range are also typically lower than those of the bobcat, which is a habitat and prey generalist (Peers *et al.* 2012, pp. 4-9).

Snow conditions also are thought to influence lynx distribution (Ruggiero *et al.* 2000b, pp. 445-449; Peers *et al.* 2012, pp. 4-9) because they are morphologically and physiologically well-adapted for hunting snowshoe hares and surviving in areas that have cold winters with deep and persistent unconsolidated snow (Murray and Boutin 1991, p. 463). Long-term snow conditions also presumably limit the winter distribution of potential lynx competitors and

predators (Buskirk *et al.* 2000a, p. 90; Krohn *et al.* 2005, p. 123; Peers *et al.* 2012, entire; also see section 2.2 above), although behavioral adaptations may offset morphological differences to some degree (e.g., Murray *et al.* 1994, entire; 1995, entire).

Based on verified data, lynx were documented historically in 24 of the contiguous United States (McKelvey *et al.* 2000a, 207-232). More recently, lynx have been documented in 3 other states after some of the lynx released into southwestern Colorado (see below) dispersed into northern New Mexico, Arizona, and Kansas (Colorado Division of Wildlife 2000, p. 3; Devineau *et al.* 2010, p. 526; 74 FR 66938), which had previously lacked verified evidence of lynx occurrence (McKelvey *et al.* 2000a, p. 210; USFS 2009, entire; 74 FR 66940-66943). However, in many states, lynx occurred very rarely as dispersers and often in anomalous habitats – usually (as described above) in association with “irruptions” (mass dispersal events) of lynx from Canada when northern snowshoe hare populations underwent dramatic cyclic declines roughly every decade. Based on our current understanding of lynx and hare habitat requirements, the Service concludes that records in at least 13 states (Arizona, Connecticut, Illinois, Indiana, Iowa, Kansas, Massachusetts, Nebraska, Nevada, New Mexico, North Dakota, Pennsylvania, and South Dakota) represent occasional dispersing lynx that arrived in places with no historical or recent evidence of the habitat quality, quantity, or distribution necessary to support resident lynx (68 FR 40099; 74 FR 66940-66942; 79 FR 54807, 54817). These states are not within the distribution of resident lynx in the DPS, and we conclude that they naturally lack the necessary habitat, hare densities, and snow conditions and that they were not capable historically, and are not capable now, of supporting resident lynx populations over time.

When it listed the DPS under the ESA, the Service defined its range as the forested portions of the remaining 14 states; 4 in the Northeast (Maine, New Hampshire, New York, Vermont), 3 in the Great Lakes Region (Michigan, Minnesota, Wisconsin), and 7 in the West (Colorado, Idaho, Montana, Oregon, Utah, Washington, Wyoming; 65 FR 16052, 16085). Some of these states, and parts of others, are thought to have historically supported only dispersing lynx or to have only occasionally supported resident breeding lynx (68 FR 40099; 74 FR 66940). Such areas were included within the range of the DPS because of the possibility that lynx could establish small, local populations in them and perhaps contribute to the persistence of the DPS, though evidence of this was (and remains) lacking (68 FR 40080; 74 FR 66938).

Based on a comprehensive, peer-reviewed analysis of verified historical lynx records that was published at about the time the DPS was listed (McKelvey *et al.* 2000a, entire) and on research and monitoring that have occurred since then, it seems likely that lynx occurred historically in some states (New York, Vermont, Wisconsin, Oregon, and Utah) only intermittently as dispersers or as small, naturally ephemeral populations; not as persistent resident breeding populations. In other states (New Hampshire, Michigan, Colorado, and Wyoming), it remains uncertain whether resident lynx occurred historically as small but persistent breeding populations or only ephemerally. Parts of the remaining states (Idaho, Maine, Minnesota, Montana, and Washington) show the strongest evidence of historical and recent (at the time of listing and since then) persistent resident populations.

In its 2003 remanded determination for the lynx DPS, the Service concluded that (1) potential lynx and hare habitats in Michigan, Oregon, Utah, Vermont, and Wisconsin were relatively small, isolated, and of marginal quality, and that available information suggested that these states did not historically or recently support resident lynx populations; (2) it was uncertain whether Colorado, New York, and Wyoming historically supported resident populations or only occasional dispersers; (3) New Hampshire probably supported a small resident population that had been extirpated; and (4) the remaining states (Idaho, Maine, Minnesota, Montana, and Washington) had the best historical and recent evidence of resident breeding populations (68 FR 40082, 40086-40095, 40097-40101). Below we provide our current understanding of these state groupings and the information available since the 2003 remand that informs this understanding.

Michigan, Oregon, Utah, Vermont, and Wisconsin - Additional information and analyses available since 2003 support the determination that Michigan (except for Isle Royale in Lake Superior) and Oregon did not historically or recently support resident lynx populations (Aubry 2006, pp. 1-2; Linden 2006, pp. 83-90), and no evidence has emerged to suggest that resident populations occurred historically or recently in Utah or Wisconsin (ILBT 2013, pp. 45, 58). Isle Royale, a 535-km² (206-mi²) island in northwestern Lake Superior that is closer to northeastern Minnesota and southern Ontario than to the rest of Michigan, is thought to have historically supported a small (perhaps 30 lynx) population that was extirpated in the 1930s due to overtrapping (Licht *et al.* 2015, p. 139; 2017, p. 505). The best available information continues to suggest that the rest of Michigan, as well as Oregon, Utah, and Wisconsin, did not historically, and do not currently, support resident lynx populations. We conclude that (1) habitats in these states are naturally incapable of supporting persistent resident populations; (2) historical and potential future occurrences of lynx in these states most likely represent occasional dispersing lynx; and (3) these states (with the possible exception of Isle Royale, MI) have not historically or recently contributed to the persistence and conservation of lynx in the DPS and are unlikely to do so in the future.

In contrast, 9 lynx occurrences were confirmed in the 530-km² (205-mi²) Nulhegan Basin of northeastern Vermont from 2003 to 2014, and breeding was confirmed in 2012; intensified surveys since then have resulted in only a single photograph of a lynx in 2014 (Bernier 2015, pp. 1-3; Bernier 2016, *pers. comm.*). This new information indicates that this small area of northernmost Vermont is at least occasionally capable of supporting a small number of resident breeding lynx. However, assessments of the amount and quality of potential lynx and hare habitat, snow conditions, and the presence and distribution of lynx competitors and predators (Hoving *et al.* 2005, pp. 746-749; Bernier 2015, entire) indicate it is unlikely that northern Vermont can support a persistent resident lynx population (79 FR 54820-54821). We conclude that this small area of Vermont only occasionally supports lynx reproduction when hare abundance and snow conditions are temporarily adequate; that it most likely represents a “sink” rather than a “source” for the regional lynx population; and that this likely represents its natural historical condition.

Colorado, New York, and Wyoming - When the Service listed the DPS in 2000, it believed that a resident lynx population occurred historically in the Southern Rocky Mountains of western Colorado and southeastern Wyoming, that lynx were also historically resident in northwestern Wyoming (part of the Northern Rocky Mountains), and that the Adirondack Mountains of northern New York may historically have supported a resident population that was extirpated by the latter half of the 1900s (65 FR 16055-16056; 16058-16059). In the 2003 remand, the Service noted inconsistencies and likely errors in historical lynx reports for the Southern Rockies, questioned its original conclusion that Colorado historically supported an isolated resident population, and concluded that it was uncertain whether a resident population occurred historically in Colorado or if historical records were of periodic dispersing lynx during “extremely high population cycles” and that a resident population never existed in southeastern Wyoming (68 FR 40081, 40091). In that rule, the Service also concluded that, despite evidence of reproduction in northwestern Wyoming (part of the GYA), potential habitat there is naturally marginal (patchier and composed of drier forest types), may be incapable of supporting a resident lynx population, and that lynx in northern Wyoming are most likely dispersers (68 FR 40090). Also in 2003, the Service concluded that it was possible resident lynx occurred in northern New York prior to 1900 but the potential habitat there is small, marginal, isolated and likely has only supported dispersing lynx since then (68 FR 40086-40087).

In Colorado, after the initial release of 96 lynx in 1999 and 2000, none were released in 2001 or 2002 (Shenk 2010, pp. 1, 4; Ivan *in* Lynx SSA Team 2016a, p. 22). From 2003-2006, another 122 lynx were released, bringing the total to 218 (Devineau *et al.* 2010, p. 526). Reproduction was documented in 2003-2006 and 2009-2010, with 48 dens documented in that time, including a third generation of Colorado-born lynx (Shenk 2010, p. 5; Ivan *in* Lynx SSA Team 2016a, p. 22). In 2010, CPW determined that all benchmarks for its lynx program had been met and had resulted in the establishment of a viable, self-sustaining lynx population (Ivan 2011b, pp. 11, 12). Intensive monitoring of the population ceased in 2010 and was replaced by an effort to develop a minimally-invasive long-term monitoring program (Ivan 2011b, entire), which used snow-tracking surveys and camera traps to document continued lynx presence in the core release area of the San Juan Mountains in 2010-11, 2014-15, and 2015-16, with evidence of reproduction also documented during that time (Ivan *et al.* 2015, p.1; Odell *et al.* 2016, entire). In its 2014 revised critical habitat designation for the DPS, the Service concluded that the historical record of verified lynx occurrence in Colorado combined with naturally highly-fragmented and isolated potential habitat and generally low snowshoe hare densities suggest that Colorado and the Southern Rockies were unlikely to have historically supported a persistent resident lynx population and that the long-term persistence of the introduced population is uncertain (79 FR 54787-54789, 54793-54795, 54816-54817). The current size of the resident lynx population in Colorado is unknown but thought to number between 100 and 250 (Ivan *in* Lynx SSA Team 2016a, p. 47). We continue to believe that available information suggests Colorado did not historically support a persistent resident lynx population and that the long-term persistence of the introduced population remains uncertain.

In northern New York, 83 lynx were released into the Adirondack Mountains in 1988-1990 (Brocke *et al.* 1993, p. 1); however, that effort failed to establish a resident breeding population

(65 FR 16055), suggesting that potential habitat there may be (and historically may have been) inadequate to support lynx persistence (68 FR 40086-40087). Information and analyses since the 2003 remand support the conclusion that New York has inadequate habitat quantity and quality (both vegetation and snow conditions) to support a resident lynx population (Hoving *et al.* 2005, pp. 746, 749). We have no information that resident lynx presently occur in New York, and our evaluation of historical records suggests that the timing of most (19; 83 percent) of the 23 verified records in the state after 1900 (McKelvey *et al.* 2000a, p. 216, table 8.2) were consistent with expected decadal irruptions of lynx from the north. The work of Hoving *et al.* (2005, entire), our evaluation of verified records of historical occurrence, and the rapid failure of the 1988-1990 lynx translocations to establish a resident population all suggest that New York has not recently and likely did not historically support a persistent resident lynx population. We conclude that (1) habitat in the Adirondack Mountains is incapable of supporting a resident lynx population, (2) verified historical records were most likely of dispersing lynx, and (3) dispersing lynx may currently and in the future continue to occur rarely and temporarily in northern New York.

In northwestern Wyoming, 18 lynx were reported to have been trapped from a small area in the Wyoming Range in winter 1971-72 (Squires and Laurion 2000, p. 338), and other sources⁴ claim that 13 lynx were trapped in the Wyoming Range in winter 1972-73. However, Reeve *et al.* (1986a, Appendix A, pp. 67-69) reported no verified (“certain”) records of lynx trapped from 1970-1982 and unverified (“probable”) accounts that included no lynx trapped in 1971, 5 trapped in 1972, and 1 trapped in 1973. These conflicting anecdotal reports of lynx occurrence/trapping records illustrate compellingly why only verified records are appropriate for consideration of lynx historical distribution, especially given evidence of historical misidentification of bobcats as lynx (McKelvey *et al.* 2000a, pp. 208-210, 227; 2008, pp. 553-554). Even if some of these anecdotal records were correct, the large numbers of lynx reported in the early 1970s correspond to the second of 2 well-documented and unprecedentedly large irruptions of lynx from Canada into the northern contiguous United States, when dispersing/transient lynx occurred temporarily in many places with little or no evidence of the historical presence of resident lynx (McKelvey *et al.* 2000a, pp. 232-242). It is more plausible that the sudden increase in lynx reportedly trapped in the Wyoming Range suggested by some of these anecdotal records would have reflected a pulse of dispersing lynx associated with that large irruption rather than a previously undocumented resident lynx population that suddenly and simultaneously became vulnerable to trapping in only a handful of winters.

However, verified information available since 2003 has documented continued presence of a small number of lynx in northwestern Wyoming as recently as 2010, including some evidence of reproduction (Squires *et al.* 2003, entire; Squires and Oakleaf 2005, entire; Murphy *et al.* 2006, entire; Endeavor Wildlife Research 2008 and 2009, entire). Additionally, at least 9 radio-marked lynx released in Colorado subsequently moved into or through the area from 1999-2010, with several settling temporarily into parts of the Wyoming Range previously occupied by native lynx (Ivan 2017, entire; see section 4.2.5, below). More recent surveys and research-related trapping

⁴ <http://www.sublettecountyjournal.com/v4n16/v4n16s7.htm>.

efforts have failed to detect lynx in this area or elsewhere in Wyoming since 2010 (79 FR 54791; Squires *in* Lynx SSA Team 2016a, pp. 20-21, 45).

The historical record and recent evidence of lynx occupancy and reproduction indicate that the GYA of northwestern Wyoming and southwestern Montana at least occasionally supports a small number of resident lynx. However, the consistency of lynx occupancy in the GYA over time remains uncertain (Lynx SSA Team 2016a, pp. 11, 45, 57). Uncertainty about whether this area consistently or only intermittently supported resident lynx historically makes it difficult to interpret their recent apparent absence from the area (Lynx SSA Team 2016a, p. 57). If residency was intermittent historically, the current apparent absence of resident lynx might be a natural condition related to the area's largely marginal or suboptimal habitat conditions - i.e., it may naturally be capable of supporting resident lynx only intermittently when habitat conditions and hare densities are optimal. In that case, future intermittent residency would be expected, but only if lynx dispersing from a source population immigrate to the GYA when habitat conditions and hare densities return to more favorable levels. Conversely, if the GYA always historically supported a small number of resident lynx but no longer does, it may suggest that some factor or factors have acted to shift the quality of the area's habitat from just barely capable of supporting a small resident population to no longer capable of doing so, potentially resulting in extirpation.

We conclude that this uncertainty cannot be resolved based on the available information but, given the protected conservation status of large areas of the GYA unit (Yellowstone and Grand Teton national parks; all or parts of the Absaroka-Beartooth, Bridger, Gros Ventre, Lee Metcalf, Northern Absaroka, Teton, and Washakie wilderness areas), its historical inability to support a robust, persistent resident population and its apparent recent inability to support any resident lynx may be a reflection of naturally marginal and patchy habitats and relatively low hare abundance in much of the unit, resulting in only an intermittent ability of this unit to support resident lynx. We note that some of the best potential habitat and highest hare densities have been documented in areas with developmental land use designations (see 4.2.3 and 4.2.5) outside parks and wilderness (e.g., the Wyoming Range/Union Pass/Togwotee Pass areas; Squires 2017, p. 2). However, most of those areas have been managed by the USFS to conserve lynx and habitats in accordance first with the recommendations in the LCAS (Reudiger *et al.* 2000, entire) and the associated conservation agreement (CA) between the USFS and the Service (USFS and USFWS 2000, entire) and subsequently with the NRLMD (USFS 2007, entire). Nonetheless, despite active management for lynx conservation and the passage, presumably, of adequate time for some previously impacted areas to regenerate back into higher-quality hare and lynx habitats, lynx apparently have failed to naturally recolonize this unit, and released lynx dispersing from Colorado have failed to maintain long-term home ranges or produce kittens in these areas. We also note, however, that extensive areas of the GYA were burned by the large, intense wildfires of 1988, and that some of those areas may soon (perhaps in the next 5-15 years) regenerate to a stage containing the dense horizontal conifer structure favorable for hares and, therefore, lynx foraging habitat, perhaps increasing the likelihood that the GYA may support resident lynx again in the near future (Lynx SSA Team 2016a, p. 46).

In southern Wyoming, all recent lynx records are of Colorado-released lynx that moved into or through the area (Devineau *et al.* 2010, fig. 1, p. 526; Ivan 2017, entire), including 1 female that in 2004 established a den on the west side of the Medicine Bow Mountains and produced 3 kittens that did not survive (Bjornlie 2016, *pers. comm.*; Ivan 2016a, *pers. comm.*; 2017, p. 3). Based on the available information, we conclude that southern Wyoming did not historically or recently support a resident lynx population and is not now capable of doing so.

New Hampshire - There were 87 confirmed lynx records in northern New Hampshire from 2006 to 2016 (though these do not represent 87 different individual lynx), with evidence of reproduction in 2010 and 2011 (79 FR 54820; NHFGD 2017, entire). Most of these records were documented during snow-track surveys in 2012-2015, with an additional 30 lynx detections recorded in 2014-2016 by remote cameras (NHFGD 2017, entire). Most records since 2006 are in the vicinity of Pittsburg in the northernmost reaches of the state, though lynx detections in 2015 and 2016 suggest a southern expansion from the area where they had been documented in 2006 through 2014 (Siren 2016a, p. 1; Siren 2016b, *pers. comm.*). Despite recent evidence of lynx residency and reproduction, the Service concluded in the 2014 revised critical habitat designation that, based on modeling of the amount of potentially suitable habitat and favorable snow conditions (Hoving *et al.* 2005, pp. 739, 749; Litvaitis and Tash 2005, p. A-298), it is unlikely that northern New Hampshire will support a resident breeding population over the long-term (79 FR 54820-54821). Siren (2014a, p. 10) suspected that the relatively few lynx detections documented in 2012-2014 may be related to the presence and abundance of bobcat, coyote, and fisher populations in much of northern New Hampshire. We conclude that northern and central New Hampshire likely supported a small resident lynx population historically that was extirpated during the latter half of the 20th century. We are uncertain whether lynx detections in northernmost New Hampshire over the past decade may represent the natural reestablishment of a small resident breeding population in the state or if it is a temporary phenomenon related to an expanding source population in neighboring northern Maine (79 FR 54821). Although bobcat populations have increased and expanded their range in this region in recent decades (Lavoie *et al.* 2009, pp. 873-874), severe winters and deep snow can substantially limit their populations (Reed 2013, pp. 29-33; McCord, 1974, pp. 433-434). Maine's bobcat harvest declined substantially after 2 deep-snow winters in 2008 and 2009 (MDIFW 2015a, p. 37). It is possible that these anomalous deep-snow winters provided a temporary competitive advantage to lynx in northern New Hampshire.

Idaho, Maine, Minnesota, Montana, and Washington - These states (along with New Hampshire, above) have the strongest historical evidence of continuous lynx presence and recent evidence of resident lynx populations (McKelvey *et al.* 2000a, pp. 211-228; 68 FR 40086-40095, 40097-40101; McKelvey *in* Lynx SSA Team 2016a, p. 11). Historical lynx records exist for much of Idaho, but many, especially in the central and southern part of the state, occurred in anomalous habitats or were associated with large irruptions of lynx from Canada to the northern contiguous United States in the early 1960s and early 1970s (McKelvey *et al.* 2000a, pp. 225-227). The historical record and recent surveys (summarized at 79 FR 54818-54820) suggest that (1) only dispersing lynx occur throughout most of Idaho, (2) habitats in many parts of the state are drier forest types that support lower densities of hares, and (3) resident lynx seem to

be confined to the Purcell, Selkirk, and Cabinet mountain ranges in the State's northern panhandle. The number of individual lynx with home ranges occurring in the northeast corner of the Idaho Panhandle is unknown but small based on the amount of potential habitat and results of recent surveys (Lucid 2016, pp. 7-11; Lucid *et al.* 2016, pp. 158-160, 180), and lynx in Idaho are part of a larger population that occurs primarily in northwestern Montana and southeastern British Columbia. In the Selkirks, a single lynx was detected in 2010 and there were multiple detections in 2015-2016. Over the last several years, radio-collar data and remote camera images have documented a single lynx with a home range in the west Cabinet Mountains and there have been detections of multiple lynx in the Purcell Mountains in or immediately adjacent to designated critical habitat (i.e., within 16 km [10 mi] of the Canada border). Detections in the Purcells in 2015-2016 included a photo of an adult lynx accompanied by juvenile lynx, the only recent evidence of lynx reproduction in Idaho, which otherwise lacks evidence of a long-term, persistent resident population (IDFG 2017a, pp. 2-3).

Maine has a long history of continual lynx presence, with evidence of a persistent resident population in much of the northern half of the state (McKelvey *et al.* 2000a, pp. 211-212; Hoving *et al.* 2003, entire;), which currently is believed to support the largest lynx population in the DPS (Vashon *et al.* 2012, pp. 50-60; 79 FR 54784-54785, 54792, 54822-54824; Vashon *in* Lynx SSA Team 2016a, p. 18). The current amount and distribution of high-quality lynx and hare habitat and the numbers of hares and resident lynx in Maine are all much larger than was suspected at the time of listing or the 2003 remand, and all are probably substantially larger now than under likely typical historical conditions. Based on habitat distribution and lynx home range data, the MDIFW estimated that this geographic unit may have supported roughly 250-320 adult lynx in 1995 and 750-1,000+ by 2003-06 (Vashon *et al.* 2012, p. 58; Vashon *in* Lynx SSA Team 2016a, p. 18]), and recent information suggests that resident lynx may be expanding to the south of the core population area (Vashon 2017, *pers. comm.*). The current lynx population in Maine is supported by the broad distribution of high-quality hare habitat that resulted from extensive, large-scale clearcutting in the 1970s and 1980s in response to a massive spruce budworm (*Choristoneura fumiferana*) outbreak (68 FR 40087; 79 FR 54792; also see section 4.2.1). As these regenerating clearcuts, which currently provide the dense horizontal structure preferred by hares, mature beyond about 35-40 years post-harvest, hare densities are expected to decline as cover and forage are reduced as a result of forest succession (Simons 2009, p. 217; Simons-Legaard *in* Lynx SSA Team 2016a, p. 16). The current lynx population in Maine is probably substantially larger than typically occurred historically under the natural disturbance regime, when relatively small amounts of the spruce-fir forests in the state are thought to have been composed of the dense young stands that provide optimal hare (and, therefore, lynx foraging) habitat (Lorimer 1977, entire; 68 FR 40094; Vashon *et al.* 2012, pp. 45, 56; 79 FR 54792). With the reduction in clearcutting and the proliferation of partial harvesting following enactment of the Maine Forest Practices Act of 1989, lynx densities in Maine are projected to decline by 55 to 65 percent by 2032 (Simons 2009, p. 217; Simons-Legaard *in* Lynx SSA Team 2016a, p. 16), perhaps to levels more consistent with likely historical conditions. Lynx in Maine likely represent the southern periphery of a larger population that occurs in northern New Brunswick and southern Quebec south of the St. Lawrence Seaway/River, which appears to partially isolate lynx in this region, demographically and genetically, from populations in the core of the species'

range (Koen *et al.* 2015, entire). Whether lynx persistence in Maine relies on immigration from Canada, and if so to what extent, is unknown.

In Minnesota, research conducted since the 2003 remand has demonstrated the continuous presence of a resident lynx population in the northeastern part of the state that seems to be the southern periphery of a larger population in southwestern Ontario (Moen *et al.* 2008b, entire; Moen *in* Lynx SSA Team 2016a, pp. 19, 39). The number of resident lynx in Minnesota is unknown but believed to be between 50 and 200 (Moen *in* Lynx SSA Team 2016a, pp. 19, 39). Hare densities and snow conditions consistently favorable for lynx appear to be restricted to the northeastern “Arrowhead” region of the state. Lynx are occasionally detected to the south and west of this region; however, those areas are dominated by bobcats. Although there are currently more lynx in Minnesota than was suspected when the DPS was listed, it is unclear whether current numbers and distribution are similar to the historical condition. The extent to which lynx persistence in Minnesota may rely on immigration from Canada is also unknown.

In Montana, research conducted since the DPS was proposed for listing has documented the continued presence and broad distribution of resident lynx in much of the northwestern portion of the state (Squires *in* Lynx SSA Team 2016a, p. 20). The number of resident lynx in northwest Montana is unknown but the area is thought to be capable of supporting between 200 and 300 resident lynx (Squires *in* Lynx SSA Team 2016a, p. 41). In this area, resident lynx occur in 3 subpopulations - the Purcell Mountains, Seeley Lake/Central, and Garnet Mountains (Squires *in* Lynx SSA Team 2016a, p. 20). No lynx were detected in the Garnet Range from 2011 to 2015, prompting concerns about the potential loss of the small resident population (perhaps 7-10 lynx) documented there in the mid-1980s and again recently from 2002 to 2010. However, whether this absence indicates the extirpation of a previously persistent resident population or the temporary loss of an historically ephemeral population is uncertain. A single lynx was verified in the Garnet Range in February 2016, indicating that natural recolonization of the area is possible; however, no other detections of that lynx or other lynx have been verified since then, and there currently remains no evidence of lynx residency in this mountain range (Lieberg 2017, *pers. comm.*). Lynx in northwestern Montana (and northern Idaho) likely represent the southern periphery of a larger population in southwestern Alberta and southeastern British Columbia. The extent to which lynx persistence in this area relies on immigration from Canada is unknown, and trapping harvest data suggest declining immigration after the mid-1980s (McKelvey *et al.* 2000a, p. 225; Squires *in* Lynx SSA Team 2016a, p. 20). In southwest Montana, few lynx and no recent evidence of reproduction have been documented in the Montana portion of the GYA where, as with the northwestern Wyoming part of the GYA (discussed above), uncertainty about whether this area consistently or only intermittently supported resident lynx historically makes it difficult to interpret their recent apparent absence from the area (Lynx SSA Team 2016a, p. 57). As elsewhere in the West, recent research and habitat assessments suggest that habitats capable of supporting resident lynx in Montana are, and historically were, naturally patchier and less-broadly distributed (Squires *et al.* 2006a, pp. 46-47; Squires *et al.* 2013, p. 191), and lynx therefore naturally rarer, than was thought when the DPS was listed (ILBT 2013, p. 23; Jackson *in* Lynx SSA Team 2016a, p. 12).

In Washington, research and monitoring conducted since the 2003 remand has continued to document a resident lynx population in the Okanogan region of the eastern Cascade Mountains in the north-central part of the state (von Kienast 2003, entire; Maletzke 2004, entire; Koehler *et al.* 2008, entire; Maletzke *et al.* 2008, entire; Maletzke *in* Lynx SSA 2016, pp. 21-22). Since at least 1985, this is the only area of the state with evidence of a resident breeding population (Koehler and Maletzke 2006, p. 4; Koehler *et al.* 2008, p. 1518; ILBT 2013, p. 58; Maletzke *in* Lynx SSA 2016, p. 21), although the Kettle Mountains in the northeastern part of the state are thought to have historically supported a small breeding population (possibly 10-20 resident lynx), and lynx are detected there occasionally (Stinson 2001, pp. 13–14; Koehler *et al.* 2008, p. 1523; USFWS 2008a, p. 2). Multiple large wildfires in this area over the last 25 years have burned about 34-37 percent of the Okanogan Lynx Management Zone (LMZ), resulting in a more than doubling of estimated female lynx home range size and a commensurate decline in the LMZ's potential lynx carrying capacity (Lewis 2016, pp. 4, 6; Maletzke *in* Lynx SSA 2016, p. 21). Although these areas should regenerate into lynx and hare habitat, it may take 35-40 years (Maletzke *in* Lynx SSA 2016, p. 21), during which time additional fire impacts could further diminish habitat availability and the likelihood that the lynx population will persist (Lynx SSA Team 2016a, p. 44; see also sections 3.4, 4.2.4, and 5.2.4).

In summary, although uncertainty remains regarding the historical distribution of resident lynx in the DPS and small breeding populations may have been lost from some places, neither broad-scale breeding range contraction nor substantial population declines in the contiguous United States from historical conditions until the DPS was listed have been documented based on verified occurrence data (68 FR 40099; 72 FR 1187; 79 FR 54798, 54815; McKelvey *in* Lynx SSA Team 2016a, p. 11). New information summarized above indicates that there are currently many more lynx in Maine and Colorado than likely occurred historically, and many more in those places and in Minnesota than was suspected when the DPS was listed. Likewise, resident lynx and some reproduction have also been documented recently in northern New Hampshire, where lynx were previously thought to have been extirpated, and in northern Vermont, which previously lacked evidence of historical lynx residency. Neither of these areas was occupied by lynx when the DPS was listed, and the expanding population in northern Maine was likely the source of lynx recolonizing northern New Hampshire and colonizing northern Vermont. Conversely, there are naturally fewer lynx and a more limited distribution of suitable habitats in most of the western United States than was previously thought (68 FR 40085, 40091-40092; ILBT 2013, p. 23), and lynx numbers in Washington have likely declined (perhaps temporarily) in response to extensive wildfire impacts to habitats over the past several decades. The geographic units evaluated in this SSA include all areas in the contiguous United States with strong historical or recent evidence of resident lynx populations. Detailed assessments of the current status and future viability of resident lynx populations and habitats in these areas are presented in chapters 4 and 5 below.

Chapter 3: Factors Influencing Viability of the DPS

In this chapter we discuss factors thought to influence the historical and current distribution and status of lynx populations in the contiguous United States, how these factors would likely

influence the future viability of the DPS, and we describe the cause-and-effects pathways of impacts associated with particular factors. We focus on the factor for which the DPS was listed under the ESA (the inadequacy of regulatory mechanisms in Federal land management plans when the DPS was listed) and on the anthropogenic influences identified by the ILBT in the revised LCAS as having the potential to exert population-level impacts on lynx and lynx habitats (ILBT 2013, pp. 68-78). Those anthropogenic influences - climate change, vegetation management, wildland fire management, and habitat loss and fragmentation - are considered the most influential factors in the future viability of the lynx DPS.

3.1 Regulatory Mechanisms

A number of activities with the potential to affect lynx habitat suitability, productivity, mortality, and movements via habitat loss or fragmentation, creation of barriers, or that otherwise alter the vegetation mosaics and prey abundances maintained historically by natural disturbance processes may occur in lynx habitats regardless of land ownership and management. The extent to which regulations guide such activities to avoid, reduce, or mitigate impacts to lynx influences the current and future likelihoods that those habitats will provide the ecological requirements to support resident lynx populations. As described in more detail below, the lynx DPS was listed as threatened because of the lack of specific conservation direction and associated regulations on some Federal lands. At that time, the available information indicated that most lynx habitat in the DPS occurred on Federal lands, predominantly in the western United States (65 FR 16061). Since then, research and monitoring have revealed that non-Federal lands contribute more to the conservation of the DPS than was known at the time of listing, particularly in the Northern Maine and Northeastern Minnesota geographic areas. Therefore, in the following sections we describe and compare the Federal regulatory environment for lynx in the DPS at the time of listing and currently, and we describe other regulatory mechanisms as they pertain to lynx on private as well as State and Tribal lands.

3.1.1 Federal Regulatory Mechanisms

Since it was listed in 2000, the DPS has been protected by the ESA's prohibition on take (under section 9), which applies to lynx wherever they occur in the DPS, regardless of land ownership. The DPS has also been protected since listing by section 7 of the ESA, which requires Federal agencies to use their authorities to conserve listed species and to consult with the Service for any actions they implement, fund, or permit (i.e., for which a "Federal nexus" exists) and which may affect lynx or lynx habitats within the DPS, again regardless of land ownership. Additionally, section 4 of the ESA requires that critical habitat, defined as the specific geographic areas containing the physical and biological features essential for the conservation of a listed species and that may require special management and protection, be designated for listed species, and section 7 prohibits the destruction or adverse modification of such designated habitats. Critical habitat was designated for the lynx DPS in 2007 and was revised in 2009 and 2014; in accordance with a September, 2016 court order (U.S. District Court MT 2016, entire), it may be revised again in the future. Section 4 of the ESA requires recovery planning for listed species; a

recovery plan for the lynx DPS has not yet been completed, but part of the purpose of this SSA is to inform near-term recovery planning direction.

Federal lands make up approximately 64 percent of the lands encompassed by the 6 geographic units evaluated in this SSA. Of those Federal lands, roughly 87 percent is managed by the U.S. Forest Service (USFS), 11 percent by the National Park Service (NPS), and 2 percent by the Bureau of Land Management (BLM). The amount of Federal land varies by unit, ranging from 1 percent in the Northern Maine Unit to over 97 percent in the GYA Unit (see table 2 and Chapter 4 for ownership in each geographic unit). Federal lands management is guided by a number of statutes and associated regulations, policies, standards, guidelines, and best management practices (BMPs) applied by managing agencies to meet legislative mandates and achieve agency missions (for a summary of relevant Acts and associated regulations and guidance, see USFWS 2014, pp. 24-34). Many of these regulatory mechanisms provide some benefits to lynx and protect lynx habitats. For example, the conservation priority in the management of NPS lands in accordance with the National Park Service Organic Act (16 USC 1 *et seq.* as amended), the National Parks and Recreation Act (Public Law 95-625), and the Wilderness Act (16 USC 1131-1136, 78 Stat. 890) likely provides an adequate regulatory framework for the conservation of lynx populations and habitats in the NPS units in which they occur (USFWS 2014, pp. 28-29, 31-33). However, it was the absence of specific management direction and conservation measures for lynx and lynx habitats in USFS and BLM land management plans that led the Service to conclude that the regulatory mechanisms in those plans at the time of listing were inadequate to ensure the conservation of the DPS. Therefore, the evaluation below focuses on the efforts of USFS and BLM, in collaboration with the Service, to address the regulatory inadequacy for which the DPS was listed.

The Service designated lynx in the contiguous United States as a DPS and listed it as threatened under the ESA in 2000 because of the inadequacy, at that time, of existing regulatory mechanisms. Specifically, at that time the Service believed that most lynx populations and potential lynx habitats (broad forest vegetation classes defined as “lynx forest types” [65 FR 16071]) in the contiguous United States occurred on Federal (USFS, NPS, and BLM) lands in the western states, and that the plans that guided management of those lands (particularly USFS and BLM lands) included “...programs, practices, and activities within the authority and jurisdiction of Federal land management agencies that may threaten lynx or lynx habitat. The lack of protection for lynx in these Plans render them inadequate to protect the species” (65 FR 16052, 16082). At that time, the Service found that USFS and BLM management plans did not adequately address risks to lynx and, as identified in the LCAS (Ruediger *et al.* 2000, pp. 2-1 through 6-3), those plans allowed actions that cumulatively could result in significant detrimental effects to lynx in the contiguous United States. As a result, the Service concluded in the final rule that the lack of Federal land management plan guidance for the conservation of lynx and the potential for those plans to allow or direct actions that could adversely affect lynx constituted a significant threat to the DPS (68 FR 40096).

In 1998, in anticipation of the DPS's listing under the ESA, regional and state directors of the Service, USFS, BLM, and NPS approved preparation of the interagency LCAS to provide a

consistent and effective approach to conserve lynx and to assist with section 7 consultation on Federal lands. An interagency Steering Committee selected a Science Team to assemble the best available scientific information on lynx and appointed the ILBT to prepare a lynx conservation strategy applicable to Federal land management in the contiguous United States (USFWS 2014, p. 15). The first edition of the LCAS was completed in January, 2000 and revised in August, 2000 (Ruediger *et al.* 2000, entire). The Steering Committee subsequently issued several amendments and clarifications, and the most recent revision of the LCAS was completed in August, 2013 (ILBT 2013, entire). The LCAS initially identified and evaluated 17 risk factors (e.g., timber and fire management, recreation, roads, livestock grazing, trapping, etc.) thought to have the potential to affect lynx habitat suitability, productivity, mortality, and movements and that may be addressed under programs, practices, and activities within the authority and jurisdiction of Federal land management agencies. These risk factors included programs or practices with the potential to result in habitat conversion, habitat fragmentation, or obstruction to lynx movement; roads or winter recreation trails that may facilitate access to historical lynx habitat by competitors; and fire suppression, which changes the vegetation mosaic maintained by natural disturbance processes. The risks identified in the 2000 LCAS were based on potential effects to lynx habitats and to individual lynx, lynx populations, or both; therefore, not all of the risks initially identified in the LCAS were thought to threaten lynx populations in the DPS (68 FR 40096). In the 2013 revised LCAS, risk factors were redefined as “Anthropogenic Influences on Lynx and Lynx Habitat,” and grouped into 2 tiers based on the potential magnitude of effects (ILBT 2013, pp. 1, 68). First tier influences (climate change, vegetation management, wildland fire management, and habitat fragmentation - discussed in the remainder of this chapter) are those with potential to negatively affect lynx populations and habitats, while second tier influences are those that may affect individual lynx but are not expected to substantially impact populations or habitats (ILBT 2013, pp. 68-85).

In addition to identifying risks, the LCAS also directed Federal agencies to map potential lynx habitat and identify lynx analysis units (LAUs) to evaluate potential impacts of management actions on lynx and snowshoe hare habitats. Finally, the LCAS developed recommended conservation measures, standards, and guidelines to be applied to lynx habitats on Federal lands that were designed to mimic historical conditions and landscape-scale disturbance patterns and to maintain or improve lynx and hare habitats at both local (project-level) and landscape scales (USFWS 2014, p. 16). After its initial completion in 2000, USFS and BLM managers within the range of the DPS agreed to implement the standards and guidelines identified in the LCAS until management plans could be formally amended to specifically address lynx conservation. In 2000, the Service, USFS, and BLM developed and adopted Canada Lynx Conservation Agreements (CAs; BLM and USFWS 2000, entire; USFS and USFWS 2000, entire) in which the BLM and USFS agreed to coordinate assessment and planning efforts with the Service to assure a comprehensive approach to lynx conservation and to use the LCAS, supporting science, and locally specific information as the basis for the approach and to streamline consultation under section 7 of the ESA. The USFS further committed to deferring any actions not involving third parties that would adversely affect lynx until such time as the Forest Plans were amended or revised to adequately conserve lynx (USFS and USFWS 2000, p. 8; 68 FR 40083).

Concurrent with development of the LCAS and interagency CAs, the USFS and BLM in 1999 completed the *Biological Assessment (BA) of the Effects of National Forest Land and Resource Management Plans and Bureau of Land Management Land Use Plans on Canada Lynx* (USFS and BLM 1999, entire). The BA identified and evaluated the potential effects on lynx of implementation of 57 USFS Land and Resource Management Plans and 56 BLM Land Use Plans throughout the 14 states in which the lynx DPS was proposed for listing. The BA concluded that the potential for adverse effects to lynx existed on each administrative unit in each geographic area and that, cumulatively, implementation of the existing plans was likely to adversely affect the DPS. It recommended that all of the plans be amended or revised to incorporate conservation measures to reduce or eliminate adverse effects to lynx (USFS and BLM 1999, p. 14). In its 2000 biological opinion on the BA, the Service evaluated the USFS and BLM plans in conjunction with the CAs described above (USFWS 2000, p. 15). The Service concluded that implementation of the existing plans in accordance with the CAs until plans could be formally amended or revised was not likely to jeopardize the DPS, but that amendments or revisions to those plans were needed to further reduce or avoid the potential for adverse effects to lynx (USFWS 2000, pp. 48-50).

In the 2003 remanded rule, the Service similarly determined that adherence to the CAs, the biological opinion, and the LCAS in assessing the impacts of Federal actions on lynx alleviated the potentially-adverse effects of Federal land management activities on lynx, but that amendment of USFS and BLM land management plans to conserve lynx would be the strongest mechanism to ensure long-term conservation of lynx and lynx habitat on Federal lands (68 FR 40096-97). It concluded that although Federal, State, and Tribal regulations and plans had reduced threats to the DPS, the inadequacy of existing regulatory mechanisms still posed a moderate, albeit lower-level threat, and would continue to do so until Federal land management plans were specifically amended to address lynx conservation (68 FR 40097).

Since the 2003 remand, most Forest Service units with lynx forest types (actual and “potential” lynx habitats) have formally amended or revised their land management plans to incorporate the conservation measures, standards, and guidelines identified in the LCAS. Because these amended and revised plans apply to secondary areas and other potential lynx habitats (i.e., all mapped habitat in all LAUs), the USFS had applied the conservation measures to many areas outside the geographic units evaluated in this SSA, including many areas that lack evidence of lynx occupancy and some with no verified lynx records. From 2004-2006, forest plans for 7 national forests with potential lynx habitat in Maine, New Hampshire, Vermont, Michigan, Minnesota, and Wisconsin were revised to include recommendations from the LCAS and the CAs (Jackson 2015, p. 6; USFWS 2014, p. 33). In 2007, the USFS completed the Northern Rockies Lynx Management Direction (NRLMD), which formally amended management plans to include lynx conservation measures, standards, and guidelines for 18 national forests covering over 150,000 km² (57,915 mi²) in Idaho, Montana, Wyoming and Utah, including over 72,000 km² (27,800 mi²) of potential lynx habitat (USFS 2007, entire; USFWS 2014, pp. 16-19; 79 FR 54813; Jackson 2015 *in* Lynx SSA Team 2016b, Appendix 3, p. 11). In 2008, the USFS similarly completed the Southern Rockies Lynx Amendment (SRLA), which formally amended forest

plans covering about 59,000 km² (22,780 mi²), including over 30,000 km² (11,583 mi²) of mapped (potential) lynx habitat on 7 national forests or national forest complexes in western Colorado and southern Wyoming (USFS 2008a, entire; Jackson 2015 *in* Lynx SSA Team 2016b, Appendix 3, p. 11). The management direction adopted in the NRLMD and SRLA was developed in accordance with the National Forest Management Act of 1976 (16 USC 1600) and the regulations that implement the statute (36 CFR 219.22), which requires public review and comment as part of the decision making process. Among national forests within the geographic units evaluated in this SSA, only those in Washington (the Okanogan-Wenatchee and Colville national forests) have not formally amended or revised their land and resource management plans. However, the plan revision process has been initiated for both forests, and both continue to manage for lynx habitats in accordance with the LCAS and the CA. Overall, the USFS manages nearly 56 percent (72,927 km² [28,157 mi²]) of the lands within the 6 geographic units evaluated in this SSA (see table 2, above), and all USFS lands are managed to support lynx conservation in accordance with formally revised or amended Forest Plans or binding conservation agreements with the Service.

The BLM manages a much smaller proportion of the lands within the SSA geographic units, nearly all of which occur in Colorado, Montana, and Wyoming. In Western Colorado (Unit 6), 10 BLM Field Offices (FOs; Colorado River Valley, Grand Junction, Gunnison, Kremmling, Little Snake, Royal Gorge, San Luis Valley, Tres Rios, Uncompahgre, and White River) contain 784 km² (303 mi²) of potential lynx habitat. These BLM areas were subject to the 2000 interagency CA; however, that CA expired in 2004 (BLM and USFWS 2000, p. 8) and was not renewed. Since then, BLM Resource Management Plans (RMPs) have been revised for 5 of the 10 FOs (Colorado River Valley, Grand Junction, Kremmling, Little Snake, and Tres Rios). RMPs for the Gunnison, Royal Gorge, San Luis Valley, Uncompahgre, and White River FOs have not been revised and do not contain specific measures for the conservation of lynx; however, these areas constitute a very small proportion of lynx habitat this unit. In western Montana (Unit 3), BLM lands in the Garnet Resource Area include 405 km² (156 mi²) of designated lynx critical habitat. In western Wyoming (Unit 5), 261 km² (101 mi²) of BLM lands on the Kemmerer and Pinedale districts are also designated as lynx critical habitat. The RMP for the Garnet area was amended in 2004 to formally adopt the conservation measures of the LCAS (BLM 2004a, 2004b, entire), and the RMPs for the Pinedale and Kemmerer districts were revised in 2008 and 2010, respectively, to adopt conservation measures and BMPs for lynx (BLM 2008, pp. A18-10 - A18-16; BLM 2010, pp. A-9 - A-12). Overall, the BLM manages just over 1 percent (1,443 km² [557 mi²]) of the lands within the 6 geographic units evaluated in this SSA (see table 2, above), most of which is actively managed to support lynx conservation.

The completion and implementation of the LCAS and its subsequent revisions, the interagency CAs, and the subsequent formal management plan revisions and amendments adopted under the NRLMD and SRLA all were undertaken to address the inadequacy of regulatory mechanisms on USFS and BLM lands for which the DPS was listed. Each incorporated the best available scientific information to develop goals, objectives, conservation measures, standards, and BMPs to guide USFS and BLM management activities at both project- and landscape-level scales to reduce or eliminate the potential for adverse effects to lynx or lynx habitats and thus

promote the conservation of the DPS (Ruediger *et al.* 2000, pp. 7-1 - 7-18; BLM and USFWS 2000, entire; USFS and USFWS 2000, entire; USFS 2007, pp. 8-30, USFS 2008a, pp. 6-19, Attachment 1-1 - 1-9). Standards and guidelines developed and implemented in accordance with the NRLMD and the SRLA were designed to promote beneficial effects and limit potentially adverse effects of management activities (vegetation management [e.g., timber harvest, precommercial thinning], wildland fire and fuels management, grazing, recreation, road/access management, energy development, etc.) on important lynx habitats including winter snowshoe hare habitat (high-quality lynx foraging habitat), denning habitat, and linkage/connectivity corridors (USFS 2007, pp. 8-30, USFS 2008a, pp. 6-19, Attachment 1-1 - 1-9). The USFS concluded that the vegetation standards adopted in the NRLMD that limit the total amount and the rate at which lynx habitat can be converted to temporarily unsuitable habitat (stand-initiation seral stage following timber harvest) ensure that the agency's timber management program is beneficial to lynx and will provide sufficient lynx habitat through time at both LAU and landscape-level scales (USFS 2007, p. 35). In its biological opinion on the NRLMD, the Service concluded that its application "...would substantially reduce or eliminate adverse effects to lynx from Forest Service land management activities on at least 94 percent of this area (National Forest System lands in the Northern Rockies), and more likely nearer to 98 percent" (USFWS 2007, p. 76). Similarly, in its 2008 biological opinion on the SRLA, the Service concluded that vegetation management standards in the SRLA would prohibit treatments that could adversely affect essential components of lynx habitat on 95.5 percent of the mapped (potential) lynx habitat in the SRLA area (National Forest System lands in the Southern Rockies; USFWS 2008b, p. 52).

In summary, all USFS and most BLM lands with known or potential lynx habitat within the range of the DPS, including all SSA geographic units that encompass USFS and BLM lands, are currently managed in accordance with the specific conservation measures and considerations identified in the LCAS and implemented via the CAs or formally revised and amended management plans described above. These agreements and revised/amended plans constitute the regulatory framework and specific regulatory mechanisms adopted to conserve lynx habitats and populations on USFS and BLM lands that support or are potentially capable of supporting them. They represent the agencies' efforts, in collaboration with the Service, to address and ameliorate the singular threat for which the lynx DPS was listed under the ESA. Although formal effectiveness monitoring has not been completed, it is clear that implementation of the CAs and revised/amended plans, and the associated programmatic and project-specific consultations between BLM/USFS and the Service in accordance with section 7 of the ESA, have resulted in avoidance/minimization of impacts to important lynx and hare habitats on Federal lands and have reduced the likelihood that management activities on these lands may adversely affect lynx in the contiguous United States. Overall, Federal lands managed by the USFS, BLM, and NPS constitute nearly 64 percent 83,683 km² [32,310 mi²] of the area evaluated in this SSA, and all but a tiny fraction of these lands are actively managed for lynx conservation.

3.1.2 State Regulations and Tribal Management

Private, State, and Tribal lands make up the remaining 36 percent of the lands encompassed by the 6 geographic units evaluated in this SSA, accounting for almost 27 percent, almost 9 percent, and 1 percent of the total, respectively (table 2). The amount of private land varies by unit, ranging from 0.3 percent in the North-central Washington Unit to over 90 percent in the Northern Maine Unit. Likewise, State ownership varies from less than 1 percent in the GYA and Western Colorado units to 36 percent in the Northeastern Minnesota Unit. Tribal lands account for about 4 percent of the Northwestern Montana/Northeastern Idaho Unit and roughly 1 percent of the Northern Maine and Northeastern Minnesota units; there are no Tribal lands in the North-central Washington, GYA, or Western Colorado units. Private, State, and Tribal lands, combined, constitute 99 percent of the lands in the Northern Maine Geographic Unit and over half of those in the Northeastern Minnesota Unit. Because both of these units support larger resident lynx populations than was suspected when the DPS was listed and, therefore, may contribute more substantially to the conservation of the DPS than was understood at the time of listing, we must evaluate the regulatory mechanisms that pertain to lynx on these lands (Lynx SSA Team 2016a, p. 54). Although private, State, and Tribal lands constitute much smaller proportions of the other 4 (western) geographic units (from about 3 percent to 16 percent, combined), important lynx habitats occur on some of those lands, and regulatory mechanisms may influence their contributions to the conservation and persistence of DPS populations or parts of them. Therefore, in this section, we summarize the relevant regulatory frameworks and mechanisms that may affect lynx on private, State, and Tribal lands within the 6 geographic units of the DPS, but with a focus on those units with the greatest proportions of these lands and on activities on these lands with the greatest potential to impact lynx.

State Wildlife Management Regulations - The following information is derived largely from the Service's 2014 Incremental Effects Memorandum prepared in support of the revised designation of critical habitat for the lynx DPS (USFWS 2014, pp. 35-38) and updated as warranted by new information. State furbearer and other wildlife management regulations benefit lynx populations in the states where they occur. In addition to State and private lands, State wildlife regulations govern hunting and trapping activities on many Federal lands where those activities are permitted. Most states within the range of the lynx prohibited trapping and hunting of lynx prior to the Service's 1998 proposal to list the DPS under the ESA, and those activities were prohibited in all states by the time the DPS was listed in 2000. All states within the lynx DPS range that allow legal bobcat harvest (1) manage in accordance with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Export Program for Appendix II Furbearer Species (USFWS 2014, pp. 25-26), (2) have distributed information to bobcat trappers and hunters on how to avoid incidental take of lynx, and (3) report all known incidental take of lynx associated with bobcat harvest to the Service's Division of Management Authority to assure that take does not exceed the amount permitted under the intra-agency section 7 consultation for the CITES Export Program (USFWS 2001, entire). Most states have also adopted special regulations in areas where lynx occur to minimize the potential for incidental take (including injury) of lynx during legal trapping of other furbearers. These efforts benefit lynx and are expected to do so in the future with continued implementation and

enforcement. Most reported incidentally-trapped lynx are released unharmed (see below), and there is no evidence that incidental trapping has had population-level impacts on lynx in the DPS range.

Unit 1: Northern Maine - In 1967, a bounty on lynx in Maine was repealed, and lynx were given complete protection from trapping and hunting. In Wildlife Management Districts where lynx may occur, the Maine Department of Inland Fisheries and Wildlife (MDIFW) has adopted special trapping regulations intended to minimize the incidental capture, injury, and death of lynx. These restrictions have varied over the past two decades, becoming more restrictive with time following a consent decree in 2008. Some of the requirements developed over time include specification of trap sizes and sets that may be used to legally harvest other furbearers and that are intended to minimize the likelihood of incidentally trapping lynx⁵ (MDIFW 2016a, pp. 8, 13). MDIFW has also prohibited the use of visual baits and visual attractants and requires mandatory reporting of incidental lynx captures. MDIFW also adopted and made available for download on its web page the interagency brochure *How to Avoid Incidental Take of Lynx while Trapping or Hunting Bobcats and other Furbearers*, modified it to be more specific to Maine, and updated it in 2015 (MDIFW 2015b, entire). MDIFW also set-up an incidental lynx capture hotline and has staff on stand-by to help immobilize, evaluate, collect tissue and/or hair samples, and release, if appropriate, any lynx reported to the hotline. From 2000 to 2016, this program has resulted in the release of 106 lynx that were reported incidentally trapped in northern Maine; during this time, 12 lynx died from traps or being illegally shot while in traps (MDIFW 2014, p. 75; MDIFW 2016b, pp. 5-10).

After preparing a habitat conservation plan (Incidental Take Plan), the MDIFW in 2014 obtained an incidental take permit from the Service for lynx trapped incidental to predator management and animal damage control activities, and the recreational furbearer trapping program in Maine. The permit allows incidental trapping of 195 lynx over a 15-year period, including 3 mortalities. After 2 lynx were killed in leaning-pole trap sets in 2014, MDIFW imposed additional trapping restrictions to further reduce mortality and injury of incidentally-trapped lynx, as required by the permit (also see Other Factors in section 4.2.1 below). In addition to prohibiting the type of leaning-pole sets that resulted in the 2 mortalities, the regulations now require exclusion devices on most killer-type traps and multiple swivels on chains, and they prohibit the use of drag sets on foothold traps.

The MDIFW also is responsible for implementing the Maine Endangered Species Act⁶ (MDIFW 2009, p. 9). Although the lynx is not State-listed as threatened or endangered because its population is believed to exceed the State's listing threshold, it is considered a species of special concern (MDIFW 2011, p 2). The MDIFW works collaboratively with the Service to conduct research and monitor lynx populations and habitats, and it recommends voluntary forest management activities to promote a sustainable supply of large, connected, and widely-distributed blocks of dense, young spruce-fir stands and to conserve large blocks of unfragmented forestland in northern and western Maine (MDIFW 2011, p. 3).

⁵ http://www.maine.gov/ifw/hunting_trapping/trapping/avoid_lynx.htm, last accessed 8.08.2016.

⁶ <http://www.mainelegislature.org/legis/statutes/12/title12sec12803.html>.

Unit 2: Northeastern Minnesota - Although lynx were unprotected and had a bounty placed on them in Minnesota prior to 1965, lynx trapping and hunting have been prohibited in Minnesota since 1984 (65 FR 16077; Moen *in* Lynx SSA Team 2016a, p. 19). Overlapping the Northeastern Minnesota SSA unit, the Minnesota Department of Natural Resources (MNDNR) has identified a specific “Lynx Management Zone” (LMZ) for which it has promulgated and enforces special trapping regulations for other furbearers in lynx habitat (MNDNR 2016a, p. 53). The MNDNR has modified trapping regulations within the LMZ to minimize the incidental take of lynx during the legal trapping of other furbearers. The regulations address specific trap types and sets, prohibit the use of certain baits and visual attractants, and require reporting of any incidentally trapped lynx to DNR conservation officers within 24 hours (MNDNR 2016a, pp. 53-55). The MNDNR also distributed to trappers the interagency brochure *How to Avoid Incidental Take of Lynx while Trapping or Hunting Bobcats and other Furbearers*. In response to a Federal court order, MDNR developed an incidental take plan designed to minimize the potential for lynx to be incidentally trapped during other legal furbearer trapping; the plan is currently under review by the Service. Like Maine, Minnesota has a State Endangered Species Statute (84.0895) which requires the MNDNR to adopt rules designating species meeting the statutory definitions of endangered, threatened, or species of special concern (State of Minnesota 2016, entire). The Statute also authorizes the MNDNR to adopt rules that regulate treatment of species designated as endangered and threatened. Also like Maine, however, Minnesota has not designated lynx as threatened or endangered under the statute. Instead it has designated the lynx a species of special concern, a designation for species that are extremely uncommon, have unique or highly specific habitat requirements, or occur on the periphery of their range in Minnesota and, therefore, deserve careful monitoring (MNDNR 2013, pp. 1-2). Thus, the MNDNR coordinates with the Service and other agencies to conduct research and monitor lynx populations and habitats.

Unit 3: Northwestern Montana/Northeastern Idaho - Lynx are designated as a species of greatest conservation need (S3; “potentially at risk”) by the State of Montana (MTFWP 2015, pp. 12, 435) and were previously considered a species of greatest conservation need (S1) by the State of Idaho (ILBT 2013, p. 57). However, in its recently revised State Wildlife Action Plan, Idaho did not retain that designation for lynx because of the lack of evidence of a persistent lynx presence in the state (IDFG 2017a, p. 4). The harvest of lynx was prohibited in Idaho and Montana beginning in 1996 and 1999, respectively. Both States participate in the CITES Export Program for bobcats, and both have promulgated and enforce special regulations for the legal trapping of other furbearers in areas occupied by lynx. In its trapping regulations, Idaho Fish and Game (IDFG) provides information on how to distinguish between bobcats and lynx and provides guidelines to reduce injury and minimize non-target catches, including lynx (IDFG 2017b, pp. 36-37). Guidelines recommend (1) a minimum 8-pound pan tension on foothold traps set for wolves, (2) specific trap types and sets for other furbearers, and (3) bait and habitat considerations when making sets. Trappers are also required to contact IDFG or local sheriff’s offices to assist with the safe release of incidentally trapped lynx. Three of 4 lynx incidentally trapped in Idaho recently were released unharmed; the other was illegally shot (IDFG 2017a, p. 3). To minimize and track the incidental capture of lynx, Montana Fish, Wildlife, and Parks

(MTFWP) has promulgated an evolving set of trapping regulations and reporting requirements since the DPS was listed (MTFWP 2016, pp. 7-10), including significant changes in 2008 that reduced the reported rate of incidental lynx captures from 1.6 per year in 2000-2007 to 0.4/year in 2008-2015 (MTFWP 2016, p. 5). In 2015, the Federal District Court of Montana approved a settlement agreement reached between the State of Montana and conservation groups aimed at protecting lynx from trapping. The case is now dismissed in accordance with the agreement, under which Montana has implemented a set of restrictions on trapping in lynx habitat. Currently, these regulations identify designated lynx protection zones (LPZs) and define acceptable trapping methods for public lands within them, which (1) prohibit the use of lethal (non-relaxing) snares for bobcats, (2) specifies the types of sets and baits or attractants that may be used for marten, fisher, and other furbearers where lynx occur, (3) requires a minimum 10-pound pan tension on foothold traps set for wolves, and (4) requires that any incidentally trapped lynx must be released unharmed if possible and reported to MTFWP (MTFWP 2016, pp. 7-10).

Unit 4: North-central Washington - Lynx harvest has been prohibited in Washington since 1991, and the lynx was listed as a State threatened species in 1993 and uplisted to endangered in 2016 (Lewis 2016, pp. iii, 1; WAFWC 2016, p. 3). Under the State's Endangered Species Program, the Washington Department of Fish and Wildlife (WADFW) developed a Lynx Recovery Plan⁷ and a Status Report⁸, and it prepares annual reports to update population and habitat information for the species. The WADFW also coordinates with the Service and other agencies to conduct research and monitor lynx populations and habitats. Additionally, the use of body-gripping traps (foothold, conibear, snares, etc.) for trapping other furbearers is prohibited in Washington (except for damage control or nuisance wildlife, which requires special permits). This avoids the potential for lynx to be incidentally captured in traps set legally for other animals.

Unit 5: GYA (Southwestern Montana and Northwestern Wyoming) - See Unit 3, above, for summary of Montana's special trapping regulations to minimize incidental take of lynx, which apply to the northern part of this unit. Lynx in Wyoming are classified as nongame wildlife, a Species of Greatest Conservation Need, and a Protected Animal by Wyoming State Statute. A classification of "State Protected" status prohibits trapping or any intentional take in the state, and lynx in Wyoming were offered full protection from trapping and hunting beginning in 1973 (ILBT 2013, p. 57). The Wyoming Game and Fish Department (WGFD) also participates in the CITES Export Program for bobcats.

Unit 6: Western Colorado - Lynx harvest has been prohibited in Colorado since 1970 and the lynx was listed as endangered in the State in 1973. Colorado participates in the CITES Export Program for bobcats, provides information to trappers and hunters on how to distinguish between lynx and bobcats, and requires immediate release of uninjured incidentally trapped lynx as well as reporting of any (uninjured, injured, or killed) incidentally trapped lynx (CPW 2015, pp. 6-7). Colorado law prohibits the use of foothold or conibear traps and snares for

⁷ <http://wdfw.wa.gov/publications/00394/>.

⁸ <http://wdfw.wa.gov/publications/01521/>.

trapping, which avoids the potential for lynx to be incidentally captured in traps set legally for other animals.

State Forest Management Regulations - Timber harvest and other forest management activities on State and private lands are governed by State regulations. Because these activities have the potential for beneficial, benign, or adverse impacts to lynx habitat depending on methods, implementation, and conservation measures, State forestry regulations may influence lynx populations, particularly where substantial amounts of lynx habitat occur on State and private lands. Below, we provide an overview of the forest management regulations in the SSA geographic units and briefly discuss their potential influences on lynx habitat. Additional details on the current and likely future influences of these regulations on lynx populations are provided below in chapters 4 and 5, particularly for the Maine and Minnesota units, where State and private lands constitute the majority of lynx habitats.

Unit 1: Northern Maine - State and private lands constitute 7 percent and 90 percent, respectively, of this SSA unit, with the vast majority of private lands managed for commercial timber production. As described above in section 2.3.2.2 and in more detail below in sections 4.2.1 and 5.2.1, the current abundance of lynx in northern Maine is attributable to the landscape-scale clear-cutting that occurred on private timber lands in the 1970s and 1980s in response to an extensive spruce budworm outbreak, which resulted in the recent unnaturally large amount of young (15 to 35 years post-harvest) regenerating forest in prime hare (lynx foraging) habitat condition. The amount and distribution of this post-clear-cut high-quality hare habitat likely peaked in the late 1990s to early 2000s, when 20-25 percent of the forest in Maine was in an early regeneration stage. The amount of young, regenerating forest at that time was 3 to 8 times higher than typical historical conditions under the natural disturbance regime, when only 3 to 7 percent of stands were likely in such condition at any given time (68 FR 40094). Current timber harvest and management on State and private lands in Maine are governed by the Maine Forest Practices Act of 1989 and administered by the Maine Forest Service within the Department of Agriculture, Conservation & Forestry to regulate, among other things, the size, arrangement, regeneration, and management of clearcuts (MEDACF 2014, pp. 42-45). Under the Act, small (up to 101 ha [250 ac]) clear-cuts are still permitted but require special permits and review and have, therefore, been replaced by various forms of partial harvest techniques; many of which are unlikely to maintain the current unnaturally high amount and distribution of high-quality hare and lynx habitat. The consequences of this large-scale shift in forest management on Maine's current lynx population, which is likely much larger than was possible under the natural historical disturbance regime, and on future conditions for lynx in this unit are discussed below in sections 4.2.1 and 5.2.1, respectively, along with other programs and factors that may influence private lands forest management in this unit.

In Maine, most private lands lack long-term management agreements to assure lynx conservation. However, in 2006 and 2007, the Natural Resource Conservation Service (NRCS) provided funds to Maine for a pilot Healthy Forest Reserve Program (HFRP) specifically to manage for Canada lynx and American marten. Under this program, 4 landowners have developed and implemented lynx management plans covering about 652 km² (252 mi²; 2.3

percent of Unit 1). All 4 landowners completed lynx plans using guidelines in the Service's *Canada lynx management guidelines for Maine* (McCollough 2007, entire). NRCS contracts with the landowners last for 10 years and these contracts expired in 2016 and 2017. The HFRP described an opportunity for enrollees to apply for Safe Harbor Agreements when their contracts expired, although none have yet indicated an interest in doing so. Management plans were written for a 70-year period; therefore, some landowners may continue voluntary lynx management activities. Many private landowners in Maine are enrolled in forest certification programs; the Sustainable Forestry Initiative (SFI) and Forest Stewardship Council (FSC). Both programs require landowners to protect endangered species and their habitats. Maine has more than 40,500 km² (15,625 mi²) of certified forestland; more than any other state⁹. It is uncertain how certified landowners address lynx management. About 10,117 km² (3,906 mi²; 35 percent of Unit 1) of private lands in northern Maine are under "working woodland" conservation easements¹⁰; although these covenants do not require specific management practices or outcomes beyond sustainable forestry, they do ensure that conversions to other land uses will never occur (MDIFW 2017, p. 2). In the past Maine private forest landowners have expressed interest in long-term commitments to lynx management plans, but to our knowledge, there are no private landowners in Maine who have committed to long-term or permanent protection and creation of lynx habitat according to the Service's lynx management guidelines or the LCAS.

State lands include Baxter State Park (809 km² [312 mi²; about 3 percent of Unit 1]) and the various lots owned and managed by the Maine Bureau of Parks and Lands (MBPL). Most of Baxter State Park is managed as wilderness area, and lynx sightings in the Park are rare, probably because most of the park is mature forest that does not support high hare densities. MBPL integrated resource policy requires that it promote the conservation of Federally-listed species. To our knowledge, with one exception, MBPL has not developed any lynx-specific management plans. However, the mitigation for the MDIFW's incidental take permit for trapping requires the maintenance, enhancement and creation of lynx habitat on about 28 percent of the MBPL's 89-km² (34-mi²) Seboomook habitat management unit during a 15-year period, with those habitats likely available to lynx beyond that time.

Unit 2: Northeastern Minnesota - State and private lands constitute about 36 percent and 16 percent, respectively, of this SSA unit. The MNDNR Division of Forestry regulates timber harvest and management on State and private lands. Under the Sustainable Forest Resources Act of 1995 (revised most recently in 2014 [MNFRC 2014, p. 1]), the Minnesota Forest Resources Council (MNFRC) has developed voluntary guidelines for site-level timber harvesting and forest management (MNFRC 2012, p. 1) that are intended for private and State landowners and include some general recommendations for wildlife including lynx. However, because they are voluntary, the extent to which these guidelines benefit lynx is uncertain (see sections 4.2.2 and 5.2.2 below).

⁹ <http://nsrforest.org/sites/default/files/uploads/seymoursherwood13full.pdf>, accessed 7.27.2017

¹⁰ <http://web.colby.edu/stateofmaine2012/state-of-large-landscape-conservation-in-maine/>, accessed 8.18.2016.

Unit 3: Northwestern Montana/Northeastern Idaho - State and private lands constitute about 4 percent and 8 percent, respectively, of this SSA unit and almost all are in the Montana portion of the unit. The Montana Department of Natural Resources and Conservation (MTDNRC) administers several laws pertaining to forest practices on State and private lands. These laws are intended to protect streamside management zones, reduce fire hazards, and provide BMPs to minimize non-point source water pollution¹¹. Although these laws may provide indirect benefits to lynx and other wildlife, they do not include specific measures to conserve or avoid impacts to lynx habitats. However, the MTDNRC and the Service collaborated on a multi-species habitat conservation plan (HCP) for forested State Trust lands that includes a Lynx Conservation Strategy to minimize impacts of forest management activities on lynx and describes conservation commitments that are based on recent information from lynx research in Montana (USFWS 2104, pp. 22-23; 79 FR 54835-54837). This HCP covers about 64 percent of the State lands in this SSA unit, regulates activities primarily associated with commercial forest management to conserve lynx foraging, denning, and connectivity habitats, and includes a 50-year commitment (79 FR 54835-54836). Additional details on this HCP and other programs for conserving lynx habitats on State and private lands in this unit are provided in section 4.2.3 below.

Unit 4: North-central Washington - State and private lands constitute about 8 percent and 0.3 percent, respectively, of this SSA unit and most are State Trust lands in the Loomis State Forest, which accounts for all 426 km² (164 mi²) of State lands in this unit. The Washington Department of Natural Resources (WADNR) administers rules guiding forest practices, such as timber harvests and road building, on State, private, and tribal forests in Washington. The Forest Practices Board, an independent State agency, adopts forest practices rules to protect water quality, fish habitat, other public resources and guide DNR's permitting process for timber harvests and other forest practices statewide. The WADNR developed a Lynx Habitat Management Plan (LHMP) for WDNR-managed lands distributed throughout north-central and northeastern Washington in areas delineated as Lynx Management Zones in the Washington State Lynx Recovery Plan (Stinson 2001, entire; Washington DNR 2006, entire). The WADNR LHMP guides timber harvest and other vegetation management on these lands, including the part of the Loomis State Forest that occurs in this unit, with the goal of creating and preserving quality lynx habitat through its forest management activities. Additional information on the LHMP is provided in sections 4.2.4 and 5.2.4 below.

Unit 5: GYA - State and private lands constitute about 0.3 percent and just over 2 percent, respectively, of this SSA unit and, combined, likely have little influence on lynx population persistence. Forestry regulations for the Montana portion of this unit are described above. In the Wyoming portion, the Wyoming State Forestry Division is responsible for the management of forested trust land across the state, including timber management and harvest, for long term forest health and productivity. Although the Division's programs may provide some indirect benefits to lynx, they do not include species- or habitat-specific regulations or conservation measures.

¹¹ <http://dnrc.mt.gov/divisions/forestry/forestry-assistance/forest-practices>, accessed 7.18.2016.

Unit 6: Western Colorado - State and private lands constitute about 0.6 percent and over 9 percent, respectively, of this SSA unit. The Colorado Department of Natural Resources and the State Division of Forestry oversee forest management activities on State and private lands in Colorado.

Tribal Management: Tribal lands contribute 1,408 km² (544 mi²; just over 1 percent) of lynx habitat to the geographic units evaluated in this SSA. This includes lands of the Passamaquoddy Tribe and the Penobscot Indian Nation in Maine (248 km² [96 mi²] in Unit 1), Grand Portage Band of Lake Superior Chippewa in Minnesota (202 km² [78 mi²] in Unit 2), and the Confederated Salish and Kootenai Tribes of the Flathead Nation - Flathead Reservation in Montana (958 km² [370 mi²] in Unit 3). Tribal management of these lands is expected to benefit lynx and lynx habitats. No tribal lands occur within SSA units 4, 5, or 6.

Unit 1: Northern Maine - Tribal lands represent less than 1 percent of this unit. The Passamaquoddy Tribe has lands enrolled in the Healthy Forest Reserve Program, described above. The Passamaquoddy Tribe's stated environmental mission is "...to protect the environment and conserve natural resources within all Passamaquoddy lands, waters, and the air we share" (Passamaquoddy Tribe 2014, entire). That of the Penobscot Indian Nation Department of Natural Resources is "...to manage, develop and protect the Penobscot Nation's natural resources in a sustainable manner that protects and enhances the cultural integrity of the Tribe" (Penobscot Indian Nation 2014, entire). Hunting, trapping or possessing lynx are prohibited in accordance with the Penobscot Indian Nation Chapter VII Inland Fish and Game Regulations – Section 204 (Penobscot Indian Nation 2012, p. 15). Tribal lands of the Aroostook Band of Micmac Indians and Houlton Band of Maliseet Indians occur immediately adjacent to this unit and lynx are thought to occupy both areas occasionally.

Unit 2: Northeastern Minnesota - Tribal lands of the Grand Portage Indian Reservation and the Bois Forte Indian Reservation—Vermillion Lake District represent 1 percent of this SSA unit. The Grand Portage Band of Chippewa has been actively working on lynx conservation since 2004. In October 2007, the Band hosted an international conference on lynx research and conservation where more than 50 researchers from the United States and Canada presented results of research on lynx diet, habitat, and management. Additionally, on-reservation timber sales and harvest practices follow an integrated management plan for priority wildlife management, sustainable economic development, and recreational uses. The Band's timber management practices benefit populations of snowshoe hares, the lynx's primary prey (Deschampe 2008, entire).

Unit 3: Northwestern Montana/Northeastern Idaho - Tribal lands of the Confederated Salish and Kootenai Tribes of the Flathead Nation, Flathead Reservation represent nearly 4 percent of this SSA unit. The mission statement of the Tribes' Fish, Wildlife, Recreation and Conservation Division is "...to protect and enhance the fish, wildlife, and wildland resources of the Tribes for continued use by the generations of today and tomorrow" (Confederated Salish and Kootenai Tribes 2014a, entire). An objective of the Tribes' Tribal Wildlife Management Program Plan is to "... develop and implement habitat management guidelines for Canadian lynx in coordination

with the Forestry Department as specified in the Forest Management Plan” (Confederated Salish and Kootenai Tribes. 2014b, p. 5). The Forest Management Plan states that “Standards for lynx management and habitat protection are set forth in the Canada Lynx Conservation Assessment and Strategy. This strategy guides land management activity in lynx foraging and denning habitat. Lynx occurrence and populations will continue to be monitored on the Reservation” (Confederated Salish and Kootenai Tribes 2000, p. 285).

In summary, a variety of State wildlife and forestry regulations and conservation efforts, along with Tribal resource management objectives, influence activities in lynx habitats across the range of the DPS. While many of these clearly benefit lynx habitats and likely contribute to the persistence of resident populations, uncertainty remains regarding the effectiveness of some regulations and voluntary programs or measures in maintaining or restoring lynx habitats. This may be especially important with regard to timber management regulations and programs on private lands, which constitute the majority of lands in the Northern Maine geographic unit and a substantial amount of the Northeastern Minnesota unit.

3.2 Climate Change

“Climate” refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements (IPCC 2007, p. 78; IPCC 2014b, pp. 119-120). The term “climate change” thus refers to a change in climate that can be identified statistically by changes in the mean and/or variability of 1 or more measures of climate (e.g., temperature or precipitation) that persists for decades or longer, whether the change is a result of natural variability, human activity, or both (IPCC 2014a, p. 5). Various types of changes in climate can have direct or indirect effects on species. These effects may be positive, neutral, or negative, and they may change over time, depending on the species and other relevant considerations, such as the effects of interactions of climate with other variables (e.g., habitat fragmentation; IPCC 2007, pp. 8–14, 18–19; Melillo *et al.* 2014, p. 12).

In 2014, the International Panel on Climate Change (IPCC) released its Fifth Assessment Report (AR5), which represents the current scientific consensus on global and regional climate change and the best synthesis of scientific data available in this rapidly changing field. The AR5 largely reaffirms the conclusions of previous reports that the global climate is warming at an accelerating rate and that this warming is largely the result of human activities and the associated release of carbon dioxide and other greenhouse gases into the atmosphere (IPCC 2014a, entire). The report concludes that the strongest and most comprehensive evidence of the impacts of climate change is in natural systems, where many species have responded by shifting their geographic ranges, seasonal activities, migration patterns, abundances, and species interactions (IPCC 2014a, p. 4). It also concludes that projected climate change during and beyond the 21st Century will likely increase extinction risk for many terrestrial and freshwater species (IPCC 2014a, pp. 14–15).

Globally, annual average temperature increased by 0.61°C (1.1°F; range = -0.53° to +2.50°C [-0.95° to +4.5°F]) from 1850-1900 to 1986-2005 (IPCC 2014a, pp. 10-11). Greenhouse gas

emissions are increasing and tracking levels predicted by models for high emissions scenarios (e.g., RCP 8.5; Hartmann *et al.* 2013, p. 180, 187-189; Peters *et al.* 2013, entire; Friedlingstein *et al.* 2014, p. 709, 712; Fuss *et al.* 2014, p. 851). Analysis of paleoclimate data indicates 20th century warming is likely to have been the largest of any century within the last 1,000 years (Folland *et al.* 2001, pp. 99-101). These changes are predicted to continue and accelerate under future climate scenarios (Hall and Fagre 2003, fig. 7; Peters *et al.* 2013, entire, fig. 1). The IPCC projects that mean surface temperature will likely increase globally by 0.4° - 2.6°C (0.7° - 4.7°F) by mid-century and 0.3° - 4.8°C (0.5° - 8.6°F) by the end of this century relative to the 1986-2005 period (IPCC 2104b, p. 60). Rogelj *et al.* (2012, entire, table 1) concluded that the change in global mean surface temperature at equilibrium by 2100 has a greater than 95 percent probability of increasing more than 1.5°C (2.7°F), a 76 percent probability of increasing 2° - 4.5°C (3.6° - 8°F), and a 14 percent probability of exceeding 4.5°C (8°F).

In North America, climate history and projections from regional climate models corroborate global models, and indicate that both eastern and western North America, including all portions of the lynx DPS, have warmed in the last century and are likely to warm by 1° to 3°C (1.8° to 5.4°F) by the year 2050 (Christensen *et al.* 2007, p. 889; IPCC 2014a, pp. 23, 31; Romero-Lankao *et al.* 2014, pp. 1452-1454) and by 1.7° to 5.6°C (3° to 10°F) by the end of this century (Melillo *et al.* 2014, p. 8). The greatest increases in winter surface air temperatures in North American are projected in the interior of Canada, but large increases (in the range of 3.9°C [7°F]) are also expected in the northern contiguous United States by 2051 to 2060 (NOAA 2007¹², entire). To date, the observed and predicted increases in surface temperatures have been greater in the Northern Rocky Mountains and the Northeast (much of the lynx DPS) than elsewhere in the contiguous United States (Romero-Lankao *et al.* 2014, pp. 1453-1454; Lynx SSA Team 2016a, pp. 14-15). For example, in the Northern Rockies at Glacier National Park, mean summer temperatures increased 1.7°C (3.0°F) between 1910 and 1980, resulting in lower snowpack, earlier spring melt, and distributional shifts in vegetation (Hall and Fagre 2003, pp. 134–139; Fagre 2005, pp. 4–9). Observed impacts attributable to climate change that may affect lynx habitats and populations include upslope and northward shifts in species distributions across multiple taxa, decreases in snow cover and duration, and increased wildfire and insect activity in boreal and subarctic conifer forests of Canada and the western United States (Vaughan *et al.* 2013, pp. 358-360; Georgakakos *et al.* 2014, p. 72; Groffman *et al.* 2014, pp. 200-205; IPCC 2014a, p. 31; Joyce *et al.* 2014, pp. 176-179; Melillo *et al.* 2014, p. 17; Romero-Lankao *et al.* 2014, pp. 1456, 1458-1461).

When we listed the DPS in 2000, the Service determined there was no evidence that global warming was a threat to lynx (65 FR 16068-16069). In 2003, we concluded that the information available regarding the potential impact of climate change on lynx was speculative and did not demonstrate a threat to lynx (68 FR 40083, 40098). In the 2005 recovery outline, we acknowledged that continued climate warming was likely to negatively affect the boreal forest ecosystem for which lynx are highly adapted, eventually causing it to recede north and/or to higher, colder elevations, potentially resulting in a substantial future reduction or even

¹² https://www.gfdl.noaa.gov/wp-content/uploads/files/research/climate-change/gfdlhighlight_vol1n6.pdf last accessed 7.27.2017.

elimination of lynx habitats from the contiguous United States (USFWS 2005, pp. 11, 14). In the 2009 and 2014 revised critical habitat designations, the Service acknowledged that new science suggested that climate change may pose a significant risk to the future conservation of the lynx DPS (74 FR 8617, 8621; 79 FR 54811).

There is growing scientific evidence of accelerated anthropogenically-influenced global climate warming during the 20th and early 21st centuries and little doubt among climatologists that this warming will continue and may increase in the future (Hansen *et al.* 2006, entire; IPCC 2014a, entire). Because the lynx is a cold-climate and snow-adapted habitat and prey specialist, there is general agreement that the species is vulnerable (highly sensitive, broadly exposed, and with limited adaptive capacity to respond favorably; therefore, predisposed to be adversely affected [IPCC 2014a, p. 5]) to climate warming and that the anticipated effects of continued warming will be adverse (not beneficial) for lynx, especially at the southern periphery of its range. Therefore, lynx biologists now identify climate change as the factor most likely to influence long-term resiliency of the DPS (Lynx SSA Team 2016a, pp. 14, 17, 19, 21-22, 35-47, 50, 53-57; ILBT 2013, pp. 43, 48, 53, 55, 63, 66, 69-71, 98).

Continued climate warming is expected to diminish boreal forest habitats and snow conditions at the southern edge of the range (all of the DPS range) that are, in some places, already patchily-distributed and perhaps only marginally capable of supporting resident lynx. Climate models project reductions in the extent of boreal forest habitats and snow conditions thought necessary to support lynx throughout the DPS, with both features predicted to migrate northward in latitude and to higher elevations (where possible; Sturm *et al.* 2001, pp. 342-342; Carroll 2007, pp. 1099-1102; Danby and Hik 2007, pp. 360-362; Gonzalez *et al.* 2007, entire; Gonzalez *et al.* 2010, pp. 761-766; McKelvey *et al.* 2011, entire; Johnston *et al.* 2012, pp. 8-11; ILBT 2013, p. 69; Koen *et al.* 2015, p. 528;). This would result in fewer, smaller, and more fragmented and isolated areas capable of supporting resident lynx and therefore smaller and more isolated lynx populations that would be more vulnerable to stochastic environmental and demographic events and genetic drift (Carroll 2007, pp. 1099–1100; Johnston *et al.* 2012, p. 11; 79 FR 54811; Schwartz 2017, pp. 4-5). Climate change has also been linked to increases in wildfire and forest insect activities in North America (Joyce *et al.* 2014, pp. 177-179; Romero-Lankao *et al.* 2014, pp. 1459-1461); two important components of boreal forest disturbance and, therefore, lynx habitat quality, quantity, and distribution. It also may affect other factors that could influence the future health of lynx populations in the DPS, such as hare/lynx cycles in Canada, disease transmission, and parasites.

Although projected climate warming is expected to reduce the future distribution and number of lynx in the DPS, there remains substantial uncertainty about the timing, rate, magnitude, and extent of potential impacts that may affect lynx populations in the DPS and how (and when) those populations may respond to increasing temperatures and altered precipitation patterns and disturbance regimes. Despite these uncertainties, specific effects of climate warming on lynx, hares, and their habitats in the DPS range that are occurring or can be reasonably anticipated include: 1) northward and upslope contraction of boreal spruce-fir forest types, 2) northward and upslope contraction of snow conditions believed to favor lynx over other terrestrial hare

predators, 3) reduced hare populations and densities, and 4) changes in the frequency, pattern, and intensity of forest disturbance events. Other potential effects of projected warming include: 5) reduced gene flow between Canadian and DPS lynx populations, 6) changes in the periodicity and amplitude of northern hare cycles, which could result in reduced lynx immigration to the DPS from Canada, and 7) increased or novel diseases and parasites. Each of these factors is discussed in more detail below.

Northward and Upslope Contraction of Boreal Spruce-fir Forest Types – Historically, boreal forest (lynx habitat) distribution in the contiguous United States has changed dramatically in response to changes in climatic conditions. It nearly disappeared from the Northeast 1,000 years ago during the interglacial warming period, then returned south into New England only in the past few centuries during the “Little Ice Age” (DeHayes *et al.* 2000, entire; Schauffler and Jacobson 2002, entire; also see 5.2.1). In the West during prehistorical periods of warmer climate, the alpine treeline ecotone (upper elevation of lynx boreal habitat) and deciduous-boreal forest ecotone (lower elevation of lynx boreal habitat) readily moved upslope in both the Northern and Southern Rockies (Legg and Baker 1980, pp. 331-332; Kearney and Luckman 1983, pp. 783-784). Boreal forest was likely continuous from the Canadian border south through the Southern Rockies of Colorado and northern New Mexico until the climate began warming and drying beginning about 15,000 years ago. That warming caused a northward and upslope retreat of the boreal zone to its current distribution, which has resulted in a naturally patchy distribution of boreal forest in the western United States that has remained relatively stable for the past 3,000 years (ILBT 2013, p. 50), with some patches largely isolated from more contiguous areas of boreal forest to the north.

Now, projected temperature increases and changes in precipitation patterns are expected to again shift the distribution of northern hemisphere ecosystems northward and up mountain slopes (McDonald and Brown 1992, pp. 411–412; Danby and Hik 2007, pp. 358–359; IPCC 2014a, pp. 3, 24-29; Groffman *et al.* 2014, p. 200). On a global or continental scale, there is general agreement that temperature is a primary determinant of treeline (Decker and Fink 2014, p. 122). Based on historical evidence, treeline is generally expected to migrate to higher elevations as temperatures warm, as permitted by local microsite conditions, although there may be a lag time in some mountain ranges (Smith *et al.* 2003, entire; Richardson and Friedland 2009, pp. 7-8, 15-16; Grafius *et al.* 2012, entire; Decker and Fink 2014, p. 67). McKenney *et al.* (2007, entire) predicted that the ranges of North American tree species will likely decrease, on average, by 12 percent and will shift northward by 700 km (435 mi) during this century. Several authors have also suggested that grasslands, aspen (*Populus* spp.) parklands, and temperate forest will expand northward, resulting in decreases in some areas that are currently boreal forest (Rizzo and Wiken 1992, p. 50; Starfield and Chapin 1996, entire; Rupp *et al.* 2000, entire; Galatowitsch *et al.* 2009, pp. 2015-2018), which could further fragment spruce-fir habitat (Iverson *et al.* 2008, p. 404; Tang and Beckage 2010, pp. 152-156; Rustad *et al.* 2012, p. 15; Simons-Legaard *et al.* 2016, p. 5). Thus, projected future warming is expected to cause another northward and upslope contraction of boreal forest in some parts of the contiguous United States (and in Canada; Groffman *et al.* 2014, p. 200), likely with negative

consequences for both lynx and snowshoe hare populations in the DPS and in southern Canada (Gonzalez *et al.* 2007, entire).

Some predicted changes to the boreal forest are already occurring, and much of the climate-induced change is occurring faster than originally predicted, suggesting rapid change as opposed to slow linear change (Soja *et al.* 2007, pp. 5-6; Settele *et al.* 2014, pp. 303-305). Globally, temperatures are increasing and snowfall is declining at the fastest rates in the high-latitude boreal forests of Canada and Eurasia (IPCC 2007, pp. 9, 52, 72), and climate models agree that winter warming across the circumboreal region will likely exceed 40 percent above the global mean winter warming (Soja *et al.* 2007, p. 4). Higher summer temperatures are thought to limit the distribution of boreal spruce-fir forests, which also are believed to be more sensitive to drought than other forests (Iverson and Prasad 2001, pp.192–196; Lenton *et al.* 2008, pp. 1788, 1791). In fact, over the past century, northward and upward (in elevation) biome shifts (the replacement at a location of one suite of species by another) in boreal ecosystems have been detected in numerous locations (Settele *et al.* 2014, pp. 278-279). Several studies (Joos *et al.* 2001, entire; Lucht *et al.* 2006, entire) suggest a temperature-increase threshold for boreal forest dieback of about 3°C (5.4°F), and some boreal forests are experiencing increases in tree mortality (Peng *et al.* 2011, entire). For example, widespread mortality and reduced growth in red spruce (*Picea rubens*; a component of lynx habitat in Unit 1) in the Northeastern United States in the 1960s to 1980s were believed to be linked to climate stress (McLaughlin *et al.* 1987, p. 501; Johnson *et al.* 1988, p. 5373).

Although increased precipitation is expected in the boreal region of Canada, particularly during the winter, it may be offset by increases in summer drought, heat stress, and evapotranspiration (Stocks *et al.* 1998, entire). Lienard *et al.* (2016, p. 7) conclude that spruce-fir forest types in New England, the Northern Great Plains, and higher elevations in the Rockies are vulnerable to drought-related stress from climate change during the next century. Nonetheless, Decker and Fink (2014, pp. 66-69) concluded that spruce-fir habitats in Colorado are only moderately vulnerable to the effects of climate change by mid-century under a moderate emissions scenario. Similarly, Keane *et al.* (*in press*, p. 209) concluded that while subalpine fir (*Abies lasiocarpa*; a major component of lynx habitats in western geographic units [3, 4, 5, and 6]) is likely to shift in distribution in the Northern Rockies, gains (expansion) will likely balance losses (contraction). They also concluded that Engelmann spruce (*Picea engelmannii*; also a major component of the 4 western geographic units), though highly sensitive to climate warming, will likely persist on the Northern Rockies landscape (Keane *et al.* *in press*, p. 213).

Upslope migration of boreal forest could occur either gradually or as a series of scattered, rapid advances as climate thresholds are crossed (Kupfer and Cairns 1996, p. 259-261) and may be limited by high winds, desiccation, and soil depths not conducive to conifer colonization. At lower elevations, the upslope movement of the deciduous-boreal ecotone is limited by excessively cold winter temperatures (generally -40°C [-40°F]), moisture (cloud, fog line), and acidic soils (Kupfer and Cairns 1996, p. 263-264). Boreal treelines in Scandinavia moved upslope an average of 40 meters (m; 131 feet [ft]), but in some locations up to 100 m (328 ft), during a recent 50-year period of warming (Kullman 1990, entire). In the Yukon, upslope

migration of spruce-fir seemed to be triggered by climate thresholds and was characterized by slow, gradual change followed by rapid advances (Danby and Hik 2007, p. 361). In Vermont, the northern hardwood-boreal ecotone moved upslope 91-119 m (299-390 ft) between 1962 and 2005 consistent with rapidly increasing cloud ceilings in the Northeast, which is believed to be closely associated with this ecotone transition (Beckage *et al.* 2008, pp. 4200-4201). Overall, the rate at which boreal forest could retreat upslope is highly speculative depending on how climate change may affect complex moisture and temperature regimes, and there could be a lag time before these community types shift (Kupfer and Cairns 1996, p. 268).

In summary, climate change is expected to further fragment boreal forest in southern Canada (Hogg 1994, entire) and in the contiguous United States, potentially reducing connectivity between lynx populations at the southern periphery of the species' range. As temperatures increase, lynx and hare habitats and, therefore, lynx distribution, are likely to recede northward and shift upward in elevation within its currently occupied range (Gonzalez *et al.* 2007, pp. 7, 13-14, 19; Beckage *et al.* 2008, entire; Jacobson *et al.* 2009, pp. 26-27, 30-31; Vashon *et al.* 2012, pp. 60, 64; ILBT 2013, p. 69). In the contiguous United States, researchers expect that lynx in mountainous habitat will, to some extent, track climate changes by using higher elevations on mountain slopes, assuming that vegetation communities supportive of lynx and hare habitats also move upslope with temperature and precipitation shifts (Gonzalez *et al.* 2007, p. 7). However, some areas of the DPS (e.g., Maine, Minnesota) lack such potential elevational refugia (Carroll 2007, pp. 1098-1102). Under a suite of emissions and climate change scenarios, boreal spruce-fir forests (lynx habitats) are projected to diminish dramatically and, under higher emissions scenarios, could largely or completely disappear from much of the DPS range by the end of this century (e.g., in Maine and Minnesota [Iverson and Prasad 2001, pp. 186, 195-196; Iverson *et al.* 2008, pp. 400, 403; Galatowitsch *et al.* 2009, pp. 2015-2016] and in the Rocky and Cascade Mountains in the west [Gonzalez *et al.* 2007, pp. 15-18; Johnston *et al.* 2012, pp. 6-13]). Under these scenarios and combined with projected impacts to snow conditions (see below), lynx populations would be anticipated to decline accordingly, with the potential loss of some DPS populations by the end of the century (Carroll 2007, pp. 1098-1102; Johnston *et al.* 2012, pp. 7-13). Although there remains much uncertainty regarding the timing, rate, and extent of modeled changes, ultimately, future northward and upslope contraction of lynx habitat in the DPS would likely result in fewer, smaller, and more isolated lynx populations that would be at increasing risk of extirpation resulting from demographic or environmental stochasticity or genetic drift.

Northward and Upslope Contraction of Snow - As described above (section 2.2), the lynx's long limbs, large feet, and low foot-loading are believed to give it an advantage in snowy conditions over terrestrial competitors and predators. Although specific snow requirements for lynx (amount/depth, quality, persistence) have not been quantified throughout the DPS range, climate warming is diminishing snow conditions in the contiguous United States. Warmer winter temperatures are reducing snow cover extent and duration and altering snow structure via a combination of a higher proportion of precipitation falling as rain, more winter thaw-freeze events, higher rates of snowmelt during winter, and earlier spring melt and runoff (Hamlet and Lettenmaier 1999, p. 1609; Brown 2000, p. 2347; Hoving 2001, pp. 73-75; Mote 2003a, p. 3-1;

Christensen *et al.* 2004, p.347; Knowles *et al.* 2006, pp. 4548–4549; Mote *et al.* 2008, entire; Pierce *et al.* 2008, entire; Abatzoglou 2011, entire; Vaughn *et al.* 2013, pp. 358-359; Georgakakos *et al.* 2014, pp. 71-85). These trends are expected to continue with projected future climate warming (Hamlet and Lettenmaier 1999, p. 1611; Christensen *et al.* 2004, p. 347; Mote *et al.* 2005, p. 48; Christensen *et al.* 2007, p. 850; McKelvey *et al.* 2011, pp. 2887-2896; IPCC 2014b, p. 62). The IPCC projects that spring snow cover in the Northern Hemisphere is likely to decrease by 7-25 percent by the end of this century (IPCC 2014b, p. 62) and that “snow season length and snow depth are very likely to decrease in most of North America except in the northernmost part of Canada where maximum snow depth is likely to increase” (Christensen *et al.* 2007, p. 850). Because lynx occurrence is correlated with prolonged periods of deep, fluffy snow, current lynx habitats would be expected to decline in value for lynx with decreases in snow condition and duration (Hoving 2001, p. 73; Carroll 2007, pp. 1100-1103; Gonzalez *et al.* 2007, entire).

Warming in recent decades corresponded to a substantial decline in snow cover duration in North America, particularly in the mountains of the western United States (Mote *et al.* 2005, pp. 47-48; Kapnick and Hall 2012, entire). These areas have historically been snow-covered from November through March, but the length of snowfall-conducive temperatures over many western mountain ranges could be reduced from about 5 months to about 3 months (December-February) by mid-century (Klos *et al.* 2014, p. 4566). Spring snowpack has already declined in many parts of the Rockies, especially since the mid-20th century, despite overall increases in winter precipitation in many places (Mote *et al.* 2005, entire; Scalzitti *et al.* 2016, pp. 5367-5368). The recent rate of decline in the snowpack of the Northern Rockies is unprecedented in the last 1,000 years (Pederson *et al.* 2011, entire), and some mountainous regions appear to be warming faster than global land averages (Rangwalla and Miller 2012, entire). However, Oyler *et al.* (2015, entire) showed that systematic errors in temperature measurements at some Snow Telemetry (SNOTEL) sites resulted in the artificial amplification of mountain climate trends. In particular, during late spring the commonly used climate datasets (PRISM and Daymet) show elevation increases of 274 m (899 ft) and 487 m (1,598 ft), respectively, in minimum (snow-inducing) temperatures, while data with the systematic errors corrected show a statistically nonsignificant change of 66 m (217 ft; IDFG 2017a, p. 6). Nonetheless, the western United States has clearly warmed over the latter half of the 20th century, and this trend is very likely to continue into the future.

Estimating trends in snowpack is challenging because the high variability in snowpack dynamics and microsite variations due to canopy cover, aspect, and elevation are not well-reflected in observation records (Hubbart *et al.* 2015, pp. 885-892; Rasouli *et al.* 2015, pp. 3937-3938; Painter *et al.* 2016, p. 149; IDFG 2017a, p. 7). Nonetheless, snowpack losses have been documented and will likely continue and could even accelerate in the future (Hamlet and Lettenmaier 1999, entire; Payne *et al.* 2004, entire; McKelvey *et al.* 2011, entire; Kapnick and Hall 2012, pp. 14-16; Ashfaq *et al.* 2013, entire; Lute *et al.* 2015, 969-971), with faster losses likely in milder climates like the Cascades and the slowest losses in the high peaks of the Northern Rockies and Southern Sierras. For every 1°C (1.8°F) increase in temperature, snowline is projected to retreat upslope about 150 m (492 ft) in elevation (Beniston 2016, p.

106). In the West, areas of contiguous spring snow cover are projected to become smaller and more isolated throughout the Columbia, Upper Missouri, and Upper Colorado Basins, with greatest losses at the southern periphery (McKelvey *et al.* 2011, pp. 2892-2896). Snow accumulation and duration are also expected to continue to decline generally in the central and eastern portion of the lynx DPS range (Christensen *et al.* 2007, p. 891; Burns *et al.* 2009, p. 31; Moen *in* Lynx SSA Team 2016, p. 19). Similarly, because of diminishing snow resources, potential lynx habitat is diminishing in the northern Appalachians and small areas in the Canadian Maritime Provinces (Carroll 2007, p. 1093). An analysis of recent and potential future snow cover under a range of IPCC climate scenarios suggests that snow conditions correlated with historical lynx occurrence records could decline by 10-20 percent across the continental United States and Canada and by 46-84 percent in the contiguous United States by the end of the century (Gonzalez *et al.* 2007, pp. 4, 7, 12-14).

Across North America, a significant increase in the proportion of winter precipitation falling as rain rather than snow has also contributed to reduced depth and persistence of winter snowpack (Brown 2000, pp. 2347-2354; Dyer and Mote 2006, entire; Georgakakos *et al.* 2014, pp. 71-72) and increased snow density (Hodgkins and Dudley 2006, entire). Because winter temperatures have increased disproportionately, especially in the coldest northern tier states (Tebaldi *et al.* 2013, entire), the amount of winter precipitation falling as rain instead of snow has also increased throughout the DPS (Huntington *et al.* 2004, entire; Knowles *et al.* 2006, entire; Feng and Hu 2007, entire). If greenhouse gas emissions continue at the current rate, by 2100, the elevation above which it snows and below which it rains could climb as much as 244 m (800 ft) in the Colorado Rockies and by 423 m (1,400 ft) in the Rockies of Idaho and Wyoming, with the snow line projected to rise by an average of 290 m (950 ft) across 6 Western mountain regions (Scalzitti *et al.* 2016, p. 1564).

Shifts in the timing of the initiation of spring runoff toward earlier dates in western North America are also well documented (Hamlet and Lettenmaier 1999, p. 1609; Brown 2000, p. 2347; Cayan *et al.* 2001, pp. 409–410; Christensen *et al.* 2004, p. 347; Mote *et al.* 2005, p. 41; Knowles *et al.* 2006, p. 4554). In addition, a feedback (albedo) effect is likely to amplify regional warming and accelerate the rate of loss of snow cover because of the reflective nature of snow and the relative heat-absorbing properties of non-snow-covered ground (Vaughan *et al.* 2013, pp. 321, 358-361). This feedback effect causes the greatest warming to occur at the interface of snow-covered and exposed areas, increasing the rate at which melting occurs in spring (Groisman *et al.* 1994a, pp. 1637–1648; Groisman *et al.* 1994b, pp. 198–200). This effect has shifted the average date of peak snowmelt 3 weeks earlier in spring in the Intermountain West (Fagre 2005, p. 4). This albedo effect is further exacerbated by atmospheric soot and desert dust on the snow surface (Painter *et al.* 2007, entire; Qian *et al.* 2009, entire) and fire-darkened landscapes (Amiro *et al.* 2006, pp. 47-49).

Warming and more frequent winter rains and thaws are also contributing to changes in snowpack structure; namely replacing deep, unconsolidated snow with harder, crustier snow. These snow conditions are expected to occur at higher latitudes (Callaghan *et al.* 2011, entire) and higher elevations in the Rockies (Abatzoglou 2011, pp. 1138-1141). As winter temperatures

rise above freezing more often, rain on snow events and winter thaws become more common, causing changes in snowpack structure, including larger grain size, basal ice layers, depth hoar (weak layers in the snowpack), and slip planes (crusts and ice layers within the snowpack; Callaghan *et al.* 2011, p. 23). The frequency of winter warm spells is correlated to the hardness of the snow surface and sinking depth, which may influence the hunting efficiency of terrestrial hare predators (Murray and Boutin 1991, entire; Murray *et al.* 1994, p. 1450; 1995, p. 1209; Stenseth *et al.* 2004, p. 10633), potentially reducing the competitive advantage lynx are believed to have over some potential competitors (Pozzanghera *et al.* 2016, pp. 698, 703). These various forms of snow compaction and structure within the snowpack could give a competitive advantage to other terrestrial predators/competitors with higher foot-loading that would normally have difficulty traveling and hunting efficiently in deep, unconsolidated snow (Murray and Boutin 1991, entire; Murray *et al.* 1994, p. 1450; Kolbe *et al.* 2007, p. 1409).

The bobcat is the closest related species to lynx in North America, and bobcats occur within or immediately adjacent to all areas occupied by resident lynx populations in the DPS. Bobcats may outcompete or displace lynx in some areas where the 2 species overlap, at both broad (Peers *et al.* 2013, entire) and local (Parker *et al.* 1983; Robinson 2006, pp. 120-129) geographic scales. In some areas of sympatry, lynx may be displaced to habitats of inferior quality, which could limit survival and productivity at the southern edge of their range (Robinson 2006, pp. 120; Peers *et al.* 2013, entire). Snow depth, consistency, and persistence likely mediate competition between the 2 species (Peers *et al.* 2012, pp. 4-9). Because of their higher foot-loading, bobcats likely hunt less efficiently than lynx in deep, unconsolidated snows (Hoving *et al.* 2005, entire; Krohn *et al.* 2005, pp. 122-129), which appear to limit bobcat mobility and distribution (Litvaitis *et al.* 1986, p. 116). Considering recent and projected future changes in snow conditions described above, stable or increasing bobcat populations in the DPS range (Roberts and Crimmins 2010, p. 170), and the predicted northward expansion of bobcats into areas currently occupied by lynx (Anderson and Lovallo 2003, p. 758; Lavoie *et al.* 2009, pp. 873-874; Roberts and Crimmins 2010, p. 172), lynx may experience increased competition and displacement by bobcats, which could influence lynx distribution and persistence at the southern edge of their range (in all DPS geographic units and in southern Canada).

Loss of favorable snow conditions could also result in increased lynx-bobcat hybridization. Thus far, hybridization has been documented in places (Minnesota, Maine, and New Brunswick) where low topographic relief and variability in winter severity may allow more interaction between the 2 species during the breeding season (Schwartz *et al.* 2004, entire; Homyack *et al.* 2008, entire; ILBT 2013, p. 34). The effects of hybridization on lynx populations in the DPS are uncertain, but it is not currently thought to be a substantial threat (Schwartz *in* Lynx SSA Team 2016a, p. 13). The hybridization rate is currently low (0.24 percent) but it could increase as bobcat populations are expected to move north with continued climate warming and related loss of snow conditions favoring lynx (Murray *et al.* 2008, p. 1465; Koen *et al.* 2015, p. 528). However, because lynx also are expected to shift northward with receding habitat conditions, it is possible that the zone of overlap between lynx and bobcats will shift northward but not increase in size, in which case an increase in hybridization rate would not be expected.

Although high-elevation areas in the western part of the DPS range (geographic units 3-6) may provide future snow refugia for lynx (Lynx SSA Team 2016a, p. 45), these areas will likely also be affected by continued climate warming, with lynx habitat distribution decreasing and isolation increasing as it moves upslope. Because recent and current rates of climate warming are much faster than occurred historically, it is possible that in these areas snow conditions favorable for lynx may move upslope at a faster rate than boreal forest vegetation, creating a mismatch of these lynx habitat elements. Thus, although it is possible that boreal forest vegetation may persist for some time, snow conditions thought to favor lynx could retreat upslope, potentially precluding lynx use of those boreal habitats and instead favoring potential competitors such as bobcats and coyotes.

Reduced Hare Populations and Densities – Climate change has also been linked to changes in the distribution of snowshoe hares in some parts of the southern edge of their range (Diefenbach *et al.* 2016, entire; Sultaire *et al.* 2016a, entire; 2016b, pp. 900-904). In Wisconsin, snowshoe hare range has contracted northward an average of 8.7 km (5.4 mi) per decade (1980-2014) and is projected to continue to recede northward with continued climate warming (Sultaire *et al.* 2016a, pp. 6-7). The authors concluded that loss of snow now contributes more than loss of habitat in determining the range of snowshoe hares in central Wisconsin (Sultaire *et al.* 2016a, entire). In Pennsylvania from 1983 to 2011, hare range contracted toward the coldest and snowiest areas in the northeastern and northwestern parts of the state, and continued warming may threaten the species' viability there (Diefenbach *et al.* 2016, entire). These 2 studies were of hare populations that do not now and apparently have not historically supported resident lynx populations, but similar contractions could occur in the future among hare populations within the range of resident lynx in the DPS.

Climate change also may affect hare populations in other ways, especially at the southern extent of its range in the DPS and in parts of southern Canada. As described above, changing snow conditions may influence lynx hunting behavior and effectiveness. For example, hard-packed snow is reported to be associated with a higher kill rate of hares by lynx and coyotes compared to soft snow (Buskirk *et al.* 2000a, p. 94; Stenseth *et al.* 2004, p. 10633). Consistently higher kill rates could generate numeric responses (population increases) by lynx and other hare predators (Hone *et al.* 2011, p. 420) that could drive hare populations to lower levels (Stenseth *et al.* 2004, p. 10633). Terrestrial hare predators are generally more diverse at the southern edge of the lynx range than in its core (Murray *et al.* 2008, pp. 1464-1465), and snow conditions that are projected to decreasingly favor lynx and increasingly favor less specialized predators (i.e., those with lower foot-loading) would be expected to result in increased predation on hares in some parts of their southern range.

Climate change is also projected to cause increases in annual precipitation and extreme precipitation events as well as hotter summers and increasing drought across most of North America (Romero-Lankao 2014, pp. 1452-1456). Because the second litters of snowshoe hares have lower survival in wet summers (Meslow and Keith 1971, entire), increased precipitation may reduce hare numbers. However, because hares have 2 to 4 litters per summer, there is opportunity for compensatory survival of later litters if one is affected by weather (Krebs *et al.*

2014, p. 1043). Decreased hare survival may also be expected during prolonged hot, dry summer conditions. Conversely, in dry western forests, increased precipitation may result in more herbaceous forage and cover, which may promote hare survival and reproduction (Ivan *et al.* 2014, p. 590). Thus, climate change may have both positive and negative effects on hares.

The shorter duration and diminished snow cover in the DPS range is also causing an increasingly pronounced mismatch in the timing of hare color change that may reduce hare survival and result in population declines by the end of the century (Mills *et al.* 2013, entire; Zimova *et al.* 2014, entire; 2016, entire). Under a high emissions scenario, projected decreases in snowpack duration by as much as 4 weeks at mid-century and 8 weeks by the end of the century (Mills *et al.* 2013, p. 7362; Zimova *et al.* 2016, p. 304) could have population-level effects on hares at the southern edge of their range (Zimova *et al.* 2016, pp. 304-305). Hares exhibit plasticity in the rate at which they can molt from white to brown in the spring, but not in the initiation date of color change or the fall transition from brown to white (Mills *et al.* 2013, pp. 7362-7363). Hares do not seem to compensate for mismatched color by changing their behavior related to concealment, thus predisposing them to predation (Zimova *et al.* 2014, pp. 5-7). There is wide variability in the timing of pelage change by individual hares within populations, and “mismatched” hares experience increased mortality rates (Zimova *et al.* 2016, p. 302). Under high emission scenarios, hare survival could decline by 11 percent by mid-century and by 23 percent by late century (Zimova *et al.* 2016, p. 304). Lower survival could result in moderate (under a medium-low emissions scenario) to steep (high emissions scenario) declines in hare populations by late century (Zimova *et al.* 2016, p. 304).

This phenotypic color mismatch resulting in reduced hare survival, in conjunction with warming temperatures and decreased snow cover duration, is suspected of contributing to northward contractions of the snowshoe hare range in Wisconsin (Sultaire *et al.* 2016a, entire; 2016b, p. 902) and Pennsylvania (Diefenbach *et al.* 2016, p. 245). It is also possible that this phenological mismatch may affect hare cycles (Zimova *et al.* 2016, p. 305). The northward contraction of hares in Wisconsin over the past 3 decades occurred concurrently with a dampening of hare population cycles (Sultaire *et al.* 2016a, p. 7).

Although increased color mismatch and associated reduced survival have the potential to result in hare population declines as described above, natural selection acting on the wide individual variation in molt phenology might enable evolutionary adaptation/rescue (Zimova *et al.* 2016, p. 305) and the color mismatch should be corrected over time by strong natural selection pressure (ILBT 2013, p. 71; Moen 2017, p. 5). Such selection pressure may explain why snowshoe hares in some parts of the southern periphery of the range do not undergo pelage change in areas with no or little snow cover (e.g., in the Pacific Northwest; Dalquest 1942, pp. 167, 174-175; Nagorsen 1983, entire) or undergo only partial change to white in winter (in Pennsylvania; Gigliotti 2016, pp. 72, 89). However, with projected accelerated climate warming, it is uncertain whether adaptation via natural selection will be able to keep pace with rapid declines in snow cover duration at the southern edge of the snowshoe hare range (Sultaire *et al.* 2016a, p. 6).

Changes in the Frequency, Pattern, and Intensity of Disturbance Events - The distribution, amount, and composition of lynx habitat could be rapidly and dramatically altered by an increasing occurrence and persistence of drought, along with associated outbreaks of insects and pathogens, wind and ice storms, and wildfires (ILBT 2013, p. 70). All of these factors are potentially interrelated with multiple feedback mechanisms, and some have a cascading effect (Dale *et al.* 2001, p. 729). For example, drought can weaken trees, increasing their vulnerability to insects and pathogens. Insects and pathogens can create dead trees or increase fuel loads, potentially increasing the risk and intensity of fire. The boreal forest is a complex and variable system, and these effects are expected to vary in time and space and may interact. These interactions may appear slowly and be difficult to detect because of the typically long life spans of trees, or they may be manifested quickly after a catastrophic perturbation to the forest.

Drought and heat stress have already affected temperate and boreal forests (Allen *et al.* 2010, entire; Settele *et al.* 2014, p. 6), particularly in the West (geographic units 3-6), where tree mortality rates have increased rapidly in recent decades (van Mantgem *et al.* 2009, entire; Garfin *et al.* 2014, p. 464, 484; Joyce *et al.* 2014, p. 177-179; Mote *et al.* 2014, p. 495-496; Wade *et al.* 2017, p. 166). Increasing growing-season temperature is expected to increase episodic drought duration and/or intensity, which could increase evaporative demand, triggering moisture stress and increased forest vulnerability to periodic widespread regional mortality events (Joye *et al.* 2014, p. 179). Although much of the United States has experienced an increase in prolonged periods of excessively high temperatures and more severe droughts over the past 50 years (Melillo *et al.* 2014, p. 15), thus far it is not possible to attribute changes in North American drought frequency to anthropogenic climate change (Romero-Lankao *et al.* 2014, p. 1456). Nonetheless, some regional trends are apparent. For example, the drought over the last decade in the western United States suggests the driest conditions in 800 years based on tree ring data (Walsh *et al.* 2014, p. 38). Drought is projected to increase in much of the West by the middle and end of this century, including lynx geographic units 5 (GYA) and 6 (Western Colorado; Walsh *et al.* 2014, p. 41, fig. 2.22). Drought conditions are also expected to increase in the Northeast (which includes Unit 1 in Maine; Horton *et al.* 2014, p. 374), Midwest (which includes Unit 2 in Minnesota; Pryor *et al.* 2014, p. 425-426), Great Plains (which includes Unit 3 in western Montana; Shafer *et al.* 2014, p. 442); Northwest (which includes Unit 4 in Washington; Mote *et al.* 2014, p. 495), and Southwest (which includes Unit 6 in Colorado; Garfin *et al.* 2014, pp. 464-465, 468), with drought severity also expected to increase in Montana (Wade *et al.* 2017, pp. 155, 158-164). Increasing drought frequency and intensity are related to increased wildfire and forest insect activity in North America, including throughout much of the DPS range, with these trends expected to continue into the future (Groffman *et al.* 2014, pp. 203, 218; Joyce *et al.* 2014, pp. 176-178, 182; Melillo *et al.* 2014, pp. 9, 17; Romero-Lankao *et al.* 2014, pp. 1448, 1460-1461, 1477).

Wildfire frequency is increasing in boreal forests of North America, and extended fire seasons and increases in the total area burned are anticipated to continue in the western United States with continued climate warming (McKenzie *et al.* 2004, entire; Westerling *et al.* 2006, entire; Romero-Lankao *et al.* 2014, pp. 1447, 1461; Westerling 2016, entire). Evaluating wildfire patterns in the western United States from 1970-2012, Westerling (2016, pp. 5-10) found rapid

and dramatic increases in the frequency of large fires, wildfire durations, and the length of the wildfire season beginning in the mid-1980s. Mesic middle- and high-elevation forest types (such as lodgepole pine [*Pinus contorta*] and spruce-fir; i.e., lynx habitats) in the Northern Rockies experienced the greatest increases. Increased spring and summer temperatures and an earlier spring snowmelt strongly influenced large wildfires, suggesting that climate is the primary driver of these changes rather than fire exclusion (suppression), which appears to have had little impact on natural fire regimes of these higher-elevation forest types in this area (ILBT 2013, p. 70). Montana and Wyoming may be acutely sensitive to climate change and, even for a very mild climate-warming scenario, the area burned in the West could roughly double by the end of the century (McKenzie et al. 2004, p. 897). Increases are most likely in dry forests with high-frequency and low-intensity fire regimes (which typically do not provide lynx habitat); in areas of moderate fire frequency and intensity and areas of low frequency and high intensity fires regimes, habitat conditions for lynx may improve (McKenzie et al. 2004, p. 899). In contrast, climate change is increasing precipitation in boreal forest regions of eastern North America, which has reduced wildfire frequency (Bergeron et al. 2001, p. 388).

Under multiple climate scenarios, large increases in fire frequency are expected for boreal forests in central and western Canada, and reduced frequency in eastern Canada - a situation that reflects past Paleoclimates that were warmer than the present (Flannigan et al. 2001, pp. 860-862). Increased fire frequency at the grassland – aspen parkland – boreal forest transition in western Canada may hasten the conversion of boreal forest to aspen parkland and aspen parkland to grassland (Flannigan et al. 2001, p. 860-861), which could affect connectivity and gene flow in lynx populations. In the DPS range, large wildfires in north-central Washington (Unit 4) have reduced lynx habitat by 35-40 percent over the past 25 years (see section 4.2.4 below). Large wildfires have also occurred recently in lynx habitats in Units 2, 3, 5 and 6, though impacts to resident populations in those units have not been documented, estimated, or modeled.

Warming and drought are also likely affecting the frequency and intensity of some eruptive boreal forest insect pests and pathogens that affect disturbance patterns in spruce-fir forests (Volney and Fleming 2000, entire; Gray 2008, entire; Groffman et al. 2014, p. 203; Joyce et al. 2014, pp. 176-178; Melillo et al. 2014, p. 17). For example, native bark beetles, such as the spruce beetle (*Dendroctonus rufipennis*) and mountain pine beetle (*Dendroctonus ponderosae*), are key agents of change in coniferous forest ecosystems in western North America and have recently defoliated millions of hectares – among the largest and most severe outbreaks in recorded history (Bentz 2009, entire; USFS 2014, entire; Ivan in Lynx SSA Team 2016a, p. 23). Drought-stressed conifers have increased vulnerability to insect attack. Warmer springs also could increase the frequency and duration of wildfires, which in turn could increase vulnerability of surviving trees to bark beetle attack (Westerling et al. 2006; Bentz et al. 2010, p. 611; ILBT 2013, p. 70). Increasing temperatures and forest homogeneity could create conditions favorable for bark beetle outbreaks that exceed natural disturbance thresholds, perhaps increasing the likelihood of additional outbreaks in the resulting large areas of even-aged forests (Raffa et al. 2008, p. 512; ILBT 2013, p. 70). By the end of the century, changes in temperatures across the boreal forests of western North America may cause markedly high probability of outbreak of

these species (Bentz *et al.* 2010. pp. 607, 609). In contrast, the range of the spruce budworm, a major pest of spruce-fir ecosystems in eastern North America, is expected to shift northward, potentially reducing vulnerability of spruce-fir forests in Maine and Minnesota (Regniere *et al.* 2012, entire).

Climate change has also been implicated in increases in severe weather events. For example, in January, 1998 a severe ice storm extensively damaged the canopy of many northeastern United States and eastern Canadian forests, causing moderate to severe forest damage to over 40,000 km² (15,444 mi²) in the Northeast United States and southern Quebec (Jones and Mulhern 1998, p. 19; Irland 2000, entire; Millward and Kraft 2004, entire). Ice storm damage to stands can range from light and patchy to total breakage of all mature stems over extensive areas (Irland 2000, entire). Similarly, in 1999, a derecho (severe wind-and hail-producing thunderstorm; Frelich *in* Lynx SSA Team 2016, p. 14) uprooted and snapped off trees in a 48 km- (30 mi-) long by 6-19 km- (4-12 mi-) wide swath of boreal forest in Unit 2 that impacted over 1,930 km² (745 mi²)¹³ of lynx habitat. It is uncertain how climate change may affect the frequency, intensity, location, and extent of ice storms and derechos; however, atmospheric warming will most likely shift the locations of prevailing ice storms northward.

In summary, natural disturbances (wildfire, forest insect outbreaks, and storms) are essential components of lynx habitats that historically have maintained the mosaic of forest stand seral stages and distributions that benefit lynx. Although these events may diminish lynx and hare habitats by removing forest cover, these impacts are typically temporary, and affected areas typically regenerate into the dense, young conifer stands that are associated with high hare and lynx densities throughout both species' ranges, including in the DPS. However, climate-mediated increases in the frequency, size, and intensity of these events may result in larger proportions of lynx habitats in a temporarily-unfavorable condition that occurs immediately post-disturbance and which may last for 10-40 years or more, depending on the nature of the disturbance and a suite of local climatic, topographical, and soil conditions. Such changes to historical disturbance regimes could affect a number of lynx demographic variables (e.g., distribution, density, survival, productivity) that influence population resiliency and, therefore, the likelihood that populations will persist on the landscape. For example, increased wildfire frequency, size, and intensity has affected over a third of the lynx habitat in Unit 4 over the past 25 years, resulting in increased lynx home ranges size and, therefore, lower density, likely reducing the population's resiliency compared to historical conditions (see sections 4.2.4 and 5.2.4, below).

Reduced Gene Flow between Canadian and DPS Lynx Populations - Koen *et al.* (2014a, entire) found that relatively lower neutral genetic diversity, lower allelic richness, and higher genetic differentiation among lynx at the trailing (southern) range edge in Ontario were correlated with high winter temperatures, low snow depth, and a low proportion of suitable habitat since the 1970s. The authors hypothesized that continued climate warming would increasingly create these unsuitable environmental conditions for lynx (e.g., milder winters with reduced snow quality, declining and fragmented boreal forest), at the trailing (southern) edge of the range. The

¹³ https://en.wikipedia.org/wiki/Boundary_Waters%E2%80%93Canadian_derecho

authors surmised that genetic structuring in southern lynx populations could be caused by a northward shift in optimal conditions, potentially resulting in isolation and extirpation of lynx populations at the trailing edge of their range or climate-induced changes in the distributions of snowshoe hare or bobcats causing lynx to shift northward. Lynx with the greatest allelic richness were found in areas with the deepest snow in the core of their range in northern Ontario (Koen *et al.* 2014a, p. 758). The authors concluded that climate warming has reduced gene flow at the receding (southern) edge of the lynx's range, and that southward gene flow from Canada into threatened United States (DPS) populations is unlikely (Koen *et al.* 2014a, p. 760). Stenseth *et al.* (2004, entire) documented population and genetic structuring in the lynx populations east and west of Hudson Bay based on differences in snow conditions on either side of this divide. This may be explained by the reluctance of lynx to disperse between areas having different snow regimes and snow quality. Snow conditions may be the key factor in the spatial, ecological, and genetic structuring of Canada lynx (Stenseth *et al.* 2004, pp. 10633-10644).

Climate warming is expected to cause increased isolation of southern lynx populations, which could reduce gene flow by reducing connectivity between populations. For example, gene flow between lynx populations in Maine, New Brunswick, and eastern Quebec and more northern populations in Canada depends on an ice bridge for dispersal across the St. Lawrence River. Although some lynx currently cross the river, Koen *et al.* (2014a, entire) found genetic structuring on either side of the river. Thus, the river already restricts gene flow. Climate-induced deteriorating ice conditions on the St. Lawrence River could further restrict gene flow between lynx populations north and south of the river (Koen *et al.* 2015, p. 528). Between 1969 and 2002 there was a 20 to 40 percent reduction in sea-ice cover during the spring thaw in the Gulf of the St. Lawrence (Johnston *et al.* 2005, pp. 214-215). Conversely, reduced ice on the St. Lawrence may prevent bobcats from dispersing northward into lynx areas in central Quebec (Koen *et al.* 2015, p. 528).

The potential for genetic drift among DPS populations would be expected to increase at some point in the future if lynx and hare habitats shift northward and upslope, as projected with continued climate warming, resulting in reduced connectivity and gene flow among smaller and more isolated lynx populations at the periphery of the range. This would result in (1) smaller and more distant potential source populations in the southern Canadian provinces, reducing the likelihood and number of immigrant lynx reaching DPS populations, and (2) smaller effective population sizes (the size of an ideal population [i.e., one that meets all the Hardy-Weinberg assumptions] that would lose heterozygosity at a rate equal to that of the observed population) among DPS populations, making them more vulnerable to drift, the consequences of which could include lower survival and reproduction rates and loss of adaptive potential (Schwartz 2017, pp. 4-5).

Changes in the Periodicity and Amplitude of Northern Hare Cycles - Climate change is altering large-scale climate systems such as the North Atlantic Oscillation (NAO), Southern Oscillation, Pacific North American Index, and North Pacific Index which, in turn, affect patterns of temperature and snow in North America (Stenseth *et al.* 2003, entire). Climate change-induced disruptions are believed to have caused or contributed to the collapse of cycles in some voles

(*Microtus* and *Myodes* spp.) in northern Europe (Cornulier *et al.* 2013, entire) and lemmings in northern Finland (Ims *et al.* 2008, pp. 81, 84). The collapse of cycles in some herbivores with high-amplitude population cycles also would imply collapses of important ecosystem functions such as pulsed flows of resources and disturbances throughout the ecosystem, including declines in predator communities (Schmitz *et al.* 2003, p. 1202; Ims *et al.* 2008, p. 85).

A common denominator of cycles that exhibit spatial gradients, such as the more pronounced snowshoe hare cycles in the northern part of its North American range, is that the cycles seem to fade as winters become shorter (Ims *et al.* 2008, p. 81). Therefore, climate has also been hypothesized to influence snowshoe hare and lynx population cycles and synchrony (Hone *et al.* 2011, entire; Krebs 2011, pp. 484-488; Yan *et al.* 2013, entire). Hone *et al.* (2011, pp. 423-424) concluded that the NAO influenced both hare and lynx numbers and could dampen cycle oscillations. Yan *et al.* (2013, p. 3269) concluded that climate forcing is not only essential in producing sustained cycles, but also in modifying cycle intervals, and that greatly reduced lynx fur harvests in Canada beginning in the mid-1980s may be linked to climate warming. However, climate data analyzed by Krebs *et al.* (2013, pp. 566-572; 2014, pp. 1042-1043, 1046-1047) failed to explain changes in hare cycle synchrony documented in Alaska and western Canada beginning in about 1995. The authors rejected the hypothesis that climatic variation was correlated with hare-cycle amplitude in their study areas (Krebs *et al.* 2014, p. 1047), and their analyses did not support concern about collapsing population cycles hypothesized by Ims *et al.* (2008, entire).

Nonetheless, changes in large-scale climate systems have already influenced the climate and snow conditions throughout the geographic range of the lynx in North America (Stenseth *et al.* 1999, entire; Brown 2000, pp. 2347-2354; Krebs *et al.* 2001, p. 34; Stenseth *et al.* 2004, entire). If climate warming produces more pronounced troughs in hare abundance cycles in the interior of Canada, lynx populations would be expected to decline, though local extinction seems unlikely (Hone *et al.* 2011, p. 424). The potential for diminished lynx populations in Canada is a concern because periodic emigration from Canada is believed to influence the demographic and genetic health of lynx populations in the DPS (McKelvey *et al.* 2000a, pp. 232-242; 2000b, pp. 32-34; Schwartz *et al.* 2002, entire; USFWS 2005, p. 2; ILBT 2013, pp. 34, 42, 47, 54, 60, 65; Squires *et al.* 2013, p. 187; 79 FR 54789, 68 FR 40091, 40097-40100). Recent lower-amplitude hare cycles in southern Canada likely resulted in lower-amplitude lynx cycles as well, possibly resulting in muted irruptions with fewer dispersing lynx emigrating from Canada into the DPS. If these reduced cycles persist, they could result in reduced demographic support and gene flow into the DPS, both of which could influence the health and persistence of resident lynx populations in the DPS.

Increased or Novel Diseases and Parasites - Climate change can increase the distribution and transmission of parasites and pathogens and alter vectors, hosts, and host-susceptibility to disease. With continued warming, some species are predicted to experience more frequent or severe disease impacts with warming while others may be relieved of pathogens (Daszak *et al.* 2000, p. 444; Harvell *et al.* 2002, entire; Brooks and Hoberg 2007, entire; Harvell *et al.* 2009, entire). Climate change is likely to cause changes to the geographic range and incidence of

insect and tick-borne diseases (Daszak *et al.* 2000, entire). No apparent climate-influenced parasites or diseases have been identified that would be expected to broadly affect lynx or snowshoe hare populations, but several lynx experts believed this is difficult to predict and remains a possibility (Lynx SSA Team 2016a, pp. 27, 37-39). A few pathogens have been documented in lynx in the DPS. For example, plague, a flea-borne disease caused by the bacterium *Yersinia pestis*, which is not native to North America, was reported for the first time in lynx in Colorado (Wild *et al.* 2006, entire). Pneumonic plague appeared to be the direct or indirect cause of death of 6 lynx released in Colorado between 2000 and 2003. When translocated from Canada and Alaska, none of the lynx had antibody titers to *Y. pestis*; it appears likely that lynx were exposed to plague by infected prey after their release in Colorado. Exposure of some lynx to feline parvovirus was detected in 6 areas in western North America (Montana-Alaska; Biek *et al.* 2002, entire). *Troglostongylus wilsoni* is a nematode that infects the lungs of lynx and bobcats (Sarmiento and Stough 1956, entire; Van Zyll de Jong 1966, entire; Kumar 1974, entire; and Reichard *et al.* 2004, entire) and was detected in Maine lynx (Vashon *et al.* 2012, p. 24). Lynx with heavy infestations have difficulty breathing and succumb to starvation, as occurred with several Maine lynx (Vashon *et al.* 2012, p. 24). Davidson *et al.* (2011, p. 242) hypothesized that toxoplasmosis could spread northward into lynx populations with changing climate and expanding ranges of humans and feral cats, cougars, and bobcats.

Summary – Well-documented climate warming over the past half-century has probably already had some impacts on lynx habitats in the DPS range, and such impacts are likely to continue and perhaps increase in the future. However, there currently is no clear evidence that climate change has had population-level effects within the DPS range or reduced the ability of habitats within the DPS range to support persistent resident lynx populations. However, such impacts would be difficult to detect and document, and lynx habitats in much of the DPS range are naturally highly-fragmented and many appear to support hare densities only marginally capable of supporting persistent lynx populations. Therefore, even relatively minor climate-mediated impacts to boreal forest habitats and snow conditions, especially to winter hare and lynx foraging habitats, may strongly influence lynx persistence in some parts of the DPS range.

Although the rates of change and magnitudes of effects of climate warming are difficult to predict, climate models agree that lynx habitat and populations are likely to decline in the future, particularly at the southern margin of the range (Carroll 2007, pp. 1098–1102; Gonzalez *et al.* 2007, entire; Peers *et al.* 2014, pp. 1129-1134) and may disappear completely or nearly so from parts of the DPS range by the end of this century or sooner, depending on the intensity of greenhouse gas emissions (Galatowitsch *et al.* 2009, pp. 2015-2017; Johnston *et al.* 2012, pp. 6–13). Remaining lynx populations in the DPS range will likely be smaller than at present and, because of small population size and increased isolation, they will likely be more vulnerable to stochastic environmental and demographic events (Carroll 2007, pp. 1100–1103) and to genetic drift (Schwartz 2017, pp. 4-5).

In addition to the factors discussed above, synergistic effects between them and other stressors (e.g., forest management, trapping, development) may intensify their impacts (Carroll 2007, entire) and could further reduce and isolate lynx populations within the DPS and reduce

connectivity between Canadian and DPS lynx populations and habitats. Declining boreal forests and snow conditions, increasing drought and fire, and increasing scale of forest insect outbreaks are currently believed to be the most important stressors for lynx in the DPS, but it is possible that other pathways are, or may also become, important. Potential climate-mediated changes in habitat, prey base, and competitor guild, along with ongoing habitat loss and fragmentation, has led some authors to question whether lynx will be able to adapt to such changes and persist at the southern periphery of the species' range (Murray *et al.* 2008, p. 1469). Largely because of the likely consequences of projected continued climate warming, lynx experts expect a decreasing likelihood that resident lynx populations will continue to persist in the future in the 5 geographic units that currently support them (Lynx SSA Team 2016a, pp. 35-47; see ch. 5, below). However, despite concerns about the long-term persistence of DPS populations, experts projected that resident lynx populations are very likely to persist in all 5 geographic units that currently support them in the near-term (year 2025) and mid-term (2050), and uncertainty was great regarding predictions beyond that time frame.

3.3 Vegetation Management

Vegetation (i.e., timber) management is the most prevalent land use throughout the lynx DPS range and can have beneficial, neutral, or adverse effects on lynx and snowshoe hare habitats and populations (65 FR 16071; 68 FR 40083; ILBT 2013, p. 71). Vegetation management affects stand age, structure, composition, and arrangement on the landscape, which are important elements of lynx and hare habitat (ILBT 2013, p. 71). Timber harvest can create, restore, and maintain lynx and hare habitats, but it and related silvicultural activities (e.g., precommercial and commercial thinning, fuels management, fire suppression) can also diminish (often temporarily) habitat quality, quantity, and distribution; alter natural disturbance regimes; and preclude attainment of the dense horizontal cover that provides high-quality hare and lynx habitat (see section 2.2). The Service listed the lynx DPS under the ESA because of the potential for such activities to adversely affect lynx habitats and populations and the absence of measures to guide them for lynx conservation on Federal lands (68 FR 40076-40101).

At the home range scale, lynx throughout the DPS range consistently occupy landscapes having the greatest snowshoe hare densities. Although forest types and the effects of forest (vegetation) management vary geographically, hare abundance throughout the DPS range is strongly correlated with a single common denominator - dense horizontal cover at ground and snow level. Such cover provides hares with a source of browse, protects them from predation, and is the most important forest structural characteristics for hares throughout their range (Ferron and Ouellet 1992, pp. 2180-2182; Wolfe *et al.* 1982, pp. 665-670; Litvaitis *et al.* 1985, entire). Hare density is directly and positively correlated with stem density (Litvaitis *et al.* 1985, p. 870; Sullivan and Sullivan 1988, pp. 803-804; Koehler 1990b, entire; Thomas *et al.* 1997, pp. 24-50; Homyack *et al.* 2006, pp. 76-79; Robinson 2006, pp. 5-37, 67-75; Scott 2009, pp. 58-93; Fuller and Harrison 2013, pp.4-6), and softwood (e.g., spruce-fir) has about 3 times more cover value than hardwoods (Litvaitis *et al.* 1985, p. 870). Young (10-40 years post-disturbance) regenerating spruce-fir forests provide optimal cover and high hare densities throughout the DPS range, and seral lodgepole pine and mature multi-storied spruce-fir stands may also

provide such conditions in the western part of the DPS range (Koehler and Brittell 1990, p. 10; Hoving *et al.* 2004, p. 290; Maletzke *et al.* 2008 p. 1477; Squires *et al.* 2010, pp. 1648, 1653–1656; McCann and Moen 2011, pp. 513-515; Berg *et al.* 2012, pp. 1483-1487; Holbrook *et al.* 2017, entire). Therefore, vegetation management practices that promote high stem density and dense horizontal cover can increase snowshoe hare densities (Conroy *et al.* 1979 pp. 684-689; Wolff 1980, pp. 115-128; Parker *et al.* 1983, pp. 783-785; Livaitis *et al.* 1985, p. 872; Monthey 1986, entire; Koehler 1990a, pp. 848-850, 1990b, entire; Robinson 2006, pp. 31-36, 62-75, 119-129; Fuller *et al.* 2007, entire; Homyack *et al.* 2007, entire; Scott 2009, pp. 8--92; McCann and Moen 2011, pp. 513-515), while forest practices that reduce dense understory generally reduce habitat quality for hares and lynx.

Historically, the dominant natural disturbance processes that created young, regenerating conifer forest conducive to hares and lynx were wildfire, insect and disease outbreaks, and wind events (Kilgore and Heinselman 1990, entire; Heinselman 1996, entire; Veblen *et al.* 1998, entire; Agee 2000, entire; Seymour *et al.* 2002, entire; Lorimer and White 2003, entire). After disturbances, forests generally develop through several stages described by Oliver (1980, pp. 155-161) as “stand initiation,” “stem exclusion,” “understory reinitiation,” and “old growth.” Stand dynamics, particularly within-stand competition for light, nutrients, and space, determine how forests grow and respond to intentional manipulations and natural disturbances (Oliver and Larson 1996, entire). The frequency and severity of disturbances have a large role in determining which tree species will dominate in a stand after the disturbance event. Snowshoe hare and lynx habitat are created during the stand initiation stage, after the young trees have established and grown tall enough (1-3 m (3-10 ft) to protrude above the snow and provide adequate horizontal cover. During the stem exclusion stage (when trees reach about 10 m [33 ft], depending on tree species) the tree crowns lift and lower branches self-prune, thus reducing the live horizontal branches providing food and cover for snowshoe hares. In the old growth stage, understory may re-develop (e.g., in forest gaps where mature trees die or fall down) and food and cover may again become available to support snowshoe hares.

Traditionally, commercial timber management of conifer forests has used a variety of silvicultural techniques (plantations, herbicide application, precommercial and commercial thinning, group selection, fuels management, and salvage and regeneration harvest) to (1) reduce tree density, promote tree growth, and select for desired species in young regenerating forests; (2) improve growth and vigor of mature trees; (3) reduce vulnerability of commercially-valuable trees to insects, disease, and fire; and (4) harvest forest products (ILBT 2013, p. 71). Just as the timing and intensity of a natural disturbance event affects the composition of the succeeding forest, the season, climate, machinery, and type of final harvest (e.g., clearcut v. partial harvest) all have a role in determining the species composition and health of the next crop of trees following management activities. Although some timber management practices may mimic natural disturbance processes, others, such as herbicide use and plantations, do not have natural analogues. Timber harvest may differ from natural disturbances in ways that may affect lynx and hare habitats, including (ILBT 2013, pp. 71-72):

- Removing most standing biomass, especially larger size classes of trees, and downed logs, which alters microsite conditions and nutrient cycling;
- Creating smaller, more dispersed patches and concentrating harvest at lower elevations in mountainous regions and on more nutrient rich soils, resulting in habitat fragmentation;
- Causing soil disturbance and compaction by heavy equipment, which may result in increased water runoff and slower tree growth at the site; or
- Giving a competitive advantage to commercially-valuable tree species and reducing the structural complexity of the forest through the application of harvest, planting, thinning, and herbicide treatments.

Therefore, vegetation management may or may not be compatible with creating, maintaining, or restoring habitats capable of supporting hares and lynx, depending on the extent to which conservation awareness and measures guide management. Vegetation management can provide snowshoe hare habitat by creating additional early-successional forest conditions in areas that are capable of, but not currently providing, dense horizontal cover; designing the appropriate size, shape and temporal pattern of treatment units (mimicking patterns created and maintained by natural disturbance regimes); retaining coarse woody debris; maintaining high stem densities in regenerated forests; and maintaining connectivity and dispersal habitat (Koehler and Brittell 1990, pp. 11-12; Homyack *et al.* 2004, pp. 141-142; Bull *et al.* 2005, entire; Fuller and Harrison 2005, p. 719). However, forest management can also diminish lynx and hare habitats by removing cover, altering natural disturbance patterns and regimes, creating unnaturally large or continuous openings, fragmenting habitat, and eliminating connectivity/dispersal habitats. Roads associated with forest management also fragment habitat and can increase access by competing predators and humans, both potentially affecting lynx habitats and populations.

Forest Products Markets - North America is the world's leading producer and consumer of wood products. Therefore, worldwide trends in forest products markets greatly affect forest management decisions, which may influence the amount and quality of lynx habitat in the DPS. Globalization of manufacturing and expanded use of electronic media have reduced demand in pulp and paper since the late 1990s, and the collapse of housing construction, which deepened with the recession of 2007-2009, has contributed to declines in United States wood products output. In recent years, the nation's forest products industry experienced a downturn in output levels not seen in decades, with considerable declines in timber harvest, mill numbers, and wood consumption since 2000, and employment losses in the hundreds of thousands (Woodall *et al.* 2011, p. 595).

Forest management decisions (e.g., to focus on hardwood or softwood production) can change dramatically in response to unpredictable and changing forest products markets. Lynx occur in forests dominated by softwood conifers; therefore, management related to softwood production and harvest has the greatest potential to affect lynx populations in the DPS range. Because they depend on demand for paper and housing, markets for softwood products are affected by economic factors that are difficult to predict and are therefore particularly volatile. For example,

the western United States, a major softwood lumber producing region, was particularly hard hit by the recession and housing collapse - forest industry employment dropped by 30 percent (nearly 80,000 workers) and annual output value fell by more than 25 percent (Keegan *et al.* 2011). Under depressed markets, landowners may reduce harvests, which may be to the detriment of lynx in some parts of the DPS (e.g., Maine and Minnesota), but to their benefit in others (the western part of the range). Likewise, rapidly expanding (recovering) softwood markets could lead to rapid and extensive harvest, with potential benefits or detriment to DPS populations, depending on local circumstances and landscape habitat conditions.

Despite depressed markets, one area of increasing interest is bioenergy production. Rising energy costs and growing concerns over global climate change have increased interest in bioenergy production, and the United States Energy Independence and Security Act (2007) mandates a 5-fold increase in biofuel production (Benjamin *et al.* 2009, p. 125). The wood pellet sector is expected to grow, although woody biomass is typically the lowest value wood commodity sold from the forest. Thus, it is questionable whether wood energy revenues would be enough to sustain forest investments and forest management into the future (Woodall *et al.* 2011, p. 601) and, therefore, potential impacts or benefits to lynx habitats and populations are uncertain.

Although management of State and Federal forest lands has been relatively stable in recent decades, management and ownership of private forest lands have been comparatively unstable. This has resulted in substantial shifts in forest management strategies, outcomes, and products. For example, in the last 2 decades in Maine, where nearly all the lynx critical habitat is on private land, about 96,315 km² (37,187 mi²; 80 percent) of commercial timber lands in the “northern forest” (Adirondacks to northern Maine) were sold to many different kinds of financial groups (Hagan *et al.* 2005). These groups have short-term investment goals and their management objectives differ from traditional commercial timber operations, resulting in changes to traditional harvest practices. Whereas the previous large commercial timber landowners focused on the forest land base as a supply for their manufacturing facilities, the new Timber Investment Management Organizations (TIMOs) and Real Estate Investment Trusts (REITs) focus on maximizing return on their investment (Jin and Sader 2006, p. 178). Initially, the effects of ownership changes were uncertain (McWilliams *et al.* 2005), but an evaluation of harvesting in the last decade indicates these landowners increased harvest rates, shortened rotation times, and shifted to managing and harvesting hardwood tree species (Jin and Sader 2006, p. 183-185). On one hand, these trends in private lands management in Maine may make lynx conservation more difficult to achieve because short-term landowners may be less interested in long-term commitments. On the other hand, some easement owners may have an incentive to manage for lynx to meet forest certification requirements.

The extensive sale of private forestlands initiated the growth of conservation easements in this region (deGooyer and Capen 2004; Lilieholm *et al.* 2010). Conservation land as a percentage of Maine's State area increased from less than 5 percent in 1987 to approximately 19 percent by 2012 (Beck *et al.* 2012, p. 15). Conservation easements restrict development but usually do not affect forest management; neither do they typically require management for lynx and other rare

species. Some private forestlands were sold to State and Federal agencies and conservation interests. For example, in recent years The Nature Conservancy purchased over 125,000 ha (310,000 ac) of private forestland in Montana and nearly 75,000 ha (185,000 ac) of private forestland in northern Maine. Lands in conservation ownership are more likely to be managed to benefit hares and lynx.

Finally, future trends in forest management will likely be affected by climate change (Irland *et al.* 2001, entire). Many models have been developed to project how United States timber production and markets may adapt to climate change (e.g., Joyce *et al.* 1995; Burton *et al.* 1998; Sohngen and Mendelsohn 1998; Perez-Garcia *et al.* 2002). Economic models predict that with continued climate warming, total United States timber inventories will increase, timber harvest will increase, and product prices will decrease relative to an assumed stable climate. Some models predict that consumers will gain from climate change while landowners in some regions will lose. The forest industry will likely adapt to climate change in many ways including using alternate tree species in manufacturing, shifts to geographic regions of the country with economic advantages in timber growth, and increasing forest plantations with new species that are favorably adapted to the new climate and markets. Many strategies have been evaluated to increase the quantity of carbon stored in North American forests (Irland *et al.* 2001) including discontinuing or greatly reducing harvest in some forests to build carbon reserves, increased recycling to reduce use of forest products, converting agricultural lands to forests, and substituting wood products for more energy-intensive products. Increased atmospheric carbon will increase forest growth slightly, except for softwood (Irland *et al.* 2001, p. 757-758). Sawtimber production, which sequesters more carbon, is expected to increase (Irland *et al.* 2001, p. 758). Expanding landscapes with older growth conifer forest to sequester carbon could benefit lynx in the West and be to the detriment of lynx in the East.

Reduced Quality of Hare Habitat - Throughout the lynx DPS, some vegetation management practices, especially thinning in young, dense regeneration; reducing overstory canopy in mature multi-story spruce-fir forests (in the West); and partial harvesting (in northern Maine) reduce the quality of boreal forest habitats for snowshoe hares and lynx. The probability of lynx occupancy of a potential home range is sensitive to small changes in average hare density (Simons 2009, pp. 89-110; Simons-Legaard *et al.* 2013, pp. 572-576). Below a threshold of about 0.5 hares/ha (0.2 hares/ac), declines in hare abundance, whether from natural population fluctuations (hare cycles) or habitat loss or fragmentation from detrimental forest practices, development, or other anthropogenic influences could be sufficient to diminish landscape carrying capacity for lynx (Scott 2009, p. 118). Such declines could result in reduced productivity (Slough and Mowat 1996, pp. 953-956), cause lynx to increase home range sizes (Scott 2009, p. 120; Ward and Krebs 1985, entire; Mowat *et al.* 2000, pp. 276-280) or, in extreme cases, to abandon their home range or cause mortality (Ward and Krebs 1985, p. 2819; Slough and Mowat 1996, pp. 956-957).

Thinning of young, dense sapling stage conifers (precommercial thinning) is a forest management practice used widely throughout the DPS to increase the growth and value of selected trees and to reduce the time to maturity of a stand of trees. Precommercial thinning

removes competing trees of the same species or shrubs and trees of other species (Daniel *et al.* 1979; Homyack *et al.* 2005, 2007). The effects of precommercial thinning are summarized in the revised Lynx Conservation Assessment and Strategy (ILBT 2013, pp. 72-73):

*Reducing the density of sapling-sized conifers in young regenerating forests to increase the growth of certain selected trees promotes more homogeneous patches and reduces the amount and density of horizontal cover, which is needed to sustain snowshoe hares (Sullivan and Sullivan 1988, Hodges 2000b, Griffin and Mills 2004, Ausband and Baty 2005, Griffin and Mills 2007, Homyack *et al.* 2007, Ellsworth 2009). Hares reach highest densities in stands with stem densities ranging from 4,600–33,210 stems/ha (1,862–13,445 stems/ac)(Wolff 1980, Parker 1984, Litvaitis *et al.* 1985, Monthey 1986, Parker 1986, Koehler 1990a, Griffin 2004, Fuller and Harrison 2005, Robinson 2006, Scott 2009), whereas thinned stands have densities of 2990 (6-foot spacing) to 1,682 (8-foot spacing) stems/ha (Pitt and Lanteigne 2008, p. 593). Precommercial thinning has been shown to reduce hare numbers by as much as 2- and 3-fold (Griffin and Mills 2004, 2007; Homyack *et al.* 2007) because of reduced cover and decreased availability of browse. Griffin and Mills (2007) reported that, if their results were representative, the practice of precommercial thinning could significantly reduce snowshoe hare populations across the range of lynx.*

*There are anecdotal examples of precommercially thinned stands that subsequently "filled in" with understory trees. Some have suggested this could be a technique to extend the time that understory trees and low limbs provide the dense horizontal cover that constitutes snowshoe hare habitat. The duration between time of thinning and regrowth to a height providing winter snowshoe hare habitat would likely vary by tree species, each having different regenerative capacities that could be influenced by a variety of local factors (e.g., topographic relief, moisture, and mineral and organic content of the soil; Baumgartner *et al.* 1984, Koch 1996). Bull *et al.* (2005) reported that the slash and coarse woody debris remaining after precommercial thinning provided both forage and cover for snowshoe hares up to a year following treatment. However, Homyack *et al.* (2007) found that snowshoe hare densities were reduced following precommercial thinning for 1–11 years post-thinning. They further suggested that after precommercial thinning, the stands did not regain the structural complexity in the understory that would be needed to support pre-treatment snowshoe hare densities. At this time, no other data are available to quantify the re-establishment of snowshoe hare habitat and over what time period, or the response by snowshoe hares, as compared with sites that were not precommercially thinned, so this remains an unproven management technique. As an alternative to standard precommercial thinning (i.e., complete thinning resulting in a homogeneous patch), Griffin and Mills (2007) suggested retaining at least 20 percent of the patch in untreated clumps of about ¼ ha (½ ac), which would maintain hare habitat in the short term. However, Lewis *et al.* (2011) found that landscapes with patches of high-quality habitat surrounded by similar vegetation supported more hares than did more fragmented landscapes composed of high-quality*

patches in a matrix of poorer-quality habitat. Further long-term studies of modified thinning methods are needed.

Abele *et al.* (2013, entire) also found that precommercial thinning reduced hare abundance in western Oregon but did not affect individual hare survival or activity patterns. Because of documented adverse effects of precommercial thinning to snowshoe hares and lynx, in 2007 and 2008 the USFS amended Forest Plans to incorporate management that would conserve lynx, including direction that prohibited precommercial thinning in most lynx foraging habitat (USFS 2007, pp. 8, 11-14, 36; USFS 2008a, pp. 6-9, 23-26). However, precommercial thinning is not regulated on private forest lands throughout the remainder of the DPS.

Particularly in western forest systems, uneven-aged management (single tree, partial harvest, and small group selection) can be used in stands with poorly developed understories, but which have the potential to develop dense horizontal cover. In such stands, removing some large trees can create openings in the canopy that mimic natural gap dynamics and maintain or stimulate multi-story attributes (ILBT 2013, p. 73). However, creation of large openings may discourage use by lynx (Koehler 1990a; von Kienast 2003; Maletzke 2004; Squires *et al.* 2010; ILBT 2013, p. 73), at least temporarily. Removing larger trees from mature multi-story stands to reduce competition and increase tree growth or resistance to forest insects may degrade lynx winter habitat by reducing horizontal cover (Robinson 2006; Koehler *et al.* 2008, Squires *et al.* 2010). Similarly, removing understory trees from mature multi-story stands also reduces dense horizontal cover, reducing winter habitat quality for both hares and lynx (ILBT 2013, p. 73).

In eastern forests, partial harvesting practices diminish (compared to regeneration following large-scale clear-cutting) the development of large patches of dense horizontal cover for snowshoe hares (Simons-Legaard *et al.* 2016, pp. 7-8). Partial harvesting broadly describes many methods of removing a portion of the overstory trees from a forest stand. Partial harvesting includes selective cuts, shelterwood cuts, and uneven-aged management. Partial harvest may be “light” (e.g., < 10 percent of trees removed) to “heavy” (e.g., 90 percent of trees removed). Since passage of the Maine Forest Practices Act in 1989, various forms of partial harvesting have replaced clearcutting as the predominant form of forest management in northern Maine (Sader *et al.* 2003, entire). In recent years, almost 172,000 ha (425,000 ac) of Maine forest are harvested annually and 96 percent of this land is partially harvested (Maine Forest Service 2016). After 28 years of extensive partial harvests, much of the northern Maine landscape has been influenced by this form of forestry, and will continue to be into the future. The popularity of this form of harvesting extends beyond Maine. From the mid-1980s to mid-1990s, partial harvesting comprised 62 percent of the harvest in the United States, and clearcuts comprised the other 38 percent. Partially harvested stands result in a wide range of residual stand conditions, but many have lower conifer stem densities and higher hardwood density than regenerating clearcuts (Robinson 2006). On average, partially harvested stands in Maine supported about 50 percent of the hare densities observed in regenerating clearcuts (Robinson 2006; Harrison *et al.* 2016 p. 55; also see sections 4.2.1 and 5.2.1, below).

Shelterwood harvesting (sometimes referred to as overstory removal) is a form of even-aged management most frequently used in hardwood and mixedwood stands in Maine (Rolek 2016, *unpubl. data*, Maine Cooperative Fish and Wildlife Research Unit), but also in spruce and fir stands (Pothier and Prevost 2008, entire). Shelterwood harvests that occur in predominantly softwood stands contribute to landscape hare densities to support lynx; however, hare density in regenerating shelterwood stands was only about half that of regenerating clearcut and herbicide-treated stands (D. Harrison, Univ. Maine, *pers. comm.* and *unpubl. data*; Harrison *et al.* 2016, p. 55). Regenerating shelterwood harvests in softwood stands are less likely to support higher landscape hare densities because they are most often done in small patches to avoid problems with windthrow, especially in wet soils (D. Harrison, Univ. Maine, *pers. comm.*). As much as 30 to 40 percent of the advanced regeneration may be damaged from repeated entries by machinery to remove the overstory (R. Seymour, Univ. Maine, *pers. comm.*). Finally, because subsequent overstory removal occurs about 15 years after the initial entry, some of the dense understory is damaged just as the stand develops conditions to support higher hare densities. The damage to the understory not only reduces the quality of the habitat for hares, but also cuts short the duration that the stand produces high-quality hare habitat.

Fuels treatment and biomass removal projects also may reduce hare and lynx habitat quality. Fuels treatment projects are typically designed to remove understory biomass and reduce stem density in forests that are outside their historical range of variability, and to clear fuels adjacent to human developments for safety or to protect investments (ILBT 2013, p. 74). Removing or reducing the understory and ladder fuels to meet those objectives reduces horizontal cover important to snowshoe hares and thus diminishes lynx habitat quality (ILBT 2013, p. 74). In the West, most of these projects occur in dry, lower-elevation forests where past fire suppression has resulted in unnatural fuel build-ups; however, these are not lynx habitat. In the Great Lakes Region, prescribed burning to reduce fuels and mimic a more natural fire regime in lynx habitat causes a short-term (10–30 years) impact on snowshoe hare habitat (ILBT 2013, p. 75). Biomass removal for energy production targets the removal of dead trees, logging slash, and small-diameter trees and shrubs. Biomass removal is similar to fuels treatments in reducing cover and habitat for snowshoe hares (ILBT 2013, p. 75).

Loss, Degradation, and Fragmentation of Boreal Forest Habitat - Forest management rarely results in conversion of lands to non-forest. In fact, forested landscapes have increased in some parts of the DPS (especially in the Northeast) because of farm abandonment and recolonization by second-growth forest. However, some forms of forest management such as selective harvesting and fire suppression can (intentionally or unintentionally) alter tree species composition away from boreal forest types that support snowshoe hares and lynx. Similarly, lack of forest management can alter tree species composition (Trani *et al.* 2001, pp. 415-417). Other stressors, such as insect outbreaks and climate change, can work in synergy with forest management to reduce boreal forest. For example, in northern New England clearcutting sometimes leads to drying of the forest floor and consequent heavy mortality in spruce and fir regeneration and increased light levels that increase hardwood competition (White and Cogbill *in* Eagar and Adams 2012, p. 32).

Plantations can convert native forest communities into monocultures of a native or exotic tree species that may lack hardwood browse for snowshoe hare. Cutting rotations can be reduced by half through mechanical site preparation, planting, and suppression of hardwood competition. Conifer stem densities in plantations range from 800-5,000 stems/ha and may support relatively low populations of snowshoe hares because of the initial wide spacing of trees (Bellefeuille *et al.* 2001, p. 44). Hare densities in plantations may increase after trees reach the sapling stage and branches intermingle at the ground level, creating horizontal cover if the lateral branches are not pruned (Parker 1984, p. 163; Parker 1986 p. 160; Roy *et al.* 2010, p. 285). However, the period of time that spruce plantations may support high hare densities in Maine and eastern Canada may be relatively short (10 to 17 years post-harvest) compared to regenerating softwood clearcuts (15-35 years post-harvest; Simons-Legaard *et al.* 2013, p. 569).

Under certain forest stand conditions, herbicide treatment may have long-term effects on stand composition and structure (MacLean and Morgan 1983; Daggett 2003), thus potentially reducing food, cover, and habitat for hares (Borrecco 1976; Bellefeuille *et al.* 2001, p. 43; Thompson *et al.* 2003 p. 462). Understory deciduous stems were lacking in stands treated with herbicide (Homyack *et al.* 2004). Although herbicide treatments reportedly do not directly affect survival, fecundity, or other demographic parameters of snowshoe hares (Sullivan 1996), treatments have indirect effects on hares via changes in vegetative cover and browse (Homyack *et al.* 2005, p. 10). In Norway, hare use of plantations was reduced up to 10 years after herbicide application (Hjeljord *et al.* 1988).

Forest management can fragment and isolate patches of high-quality hare habitat (Simons-Legaard *et al.* 2016). Fragmentation of the already naturally patchy pattern of lynx habitat in much of the contiguous United States can affect lynx by reducing their prey base and increasing the energetic costs of using habitat within their home ranges. Buskirk *et al.* (2000a) identified direct effects of fragmentation on lynx to include creation of openings that potentially increase access by competing carnivores, increasing the edge between early-successional habitat and other habitats, and changes in the structural complexities and amounts of seral forests within the landscape. At some point, landscape-scale fragmentation from forest management can make patches of foraging habitat too small and too distant from each other to be effectively accessed by lynx as part of their home range. For example, in Maine the proliferation of partial harvesting will actually increase the patches of high-quality hare habitat by 57 percent, but the average size of patches will be diminished by 87 percent, and patches will become more isolated (Simons-Legaard *et al.* 2016, pp. 5-6).

Changes in Frequency and Pattern of Disturbance Events - Prior to European settlement, the dominant natural disturbance processes that created early-successional stages within the range of the lynx were wildfire, insect and disease outbreaks, and wind events (Kilgore and Heinselman 1990; Veblen *et al.* 1994; Heinselman 1996; Agee 2000; Seymour *et al.* 2002; Lorimer and White 2003). In the DPS range, fire was more important in the West and Great Lakes areas and less a factor in the Northeast, where insects and wind events predominated. Today, natural disturbances, especially fire and insect outbreaks, remain the predominant forms of disturbance in boreal forests throughout much of the lynx's range, including the western

contiguous United States, where they also influence and interact with forest management. However, forest management (i.e., timber harvest) is an important disturbance agent in some boreal forest types in the DPS range and, in some instances has greatly altered the natural disturbance regime. For example, prior to logging, the Acadian forest in Maine and eastern Canada likely exhibited forest gap dynamics similar to some parts of the West today, and true stand-replacing disturbances were quite uncommon with recurrence intervals of hundreds to thousands of years. After several centuries of forest management, stand age structures in the Acadian forest have become simplified, and commercial timber rotations (harvesting schedules) are a fraction (15 to 40 percent) of the lifespan of boreal tree species (Seymour 2002). Although the prevalence of these younger even-aged forest stands on the landscape may benefit hares and lynx in Maine, forestry has shifted the species composition of Maine's forest to tree species favored by frequent harvest disturbance, such as red maple (*Acer rubrum*), paper birch (*Betula papyrifera*), aspen (big-toothed [*Populus grandidentata*] and quaking [*P. tremuloides*]), and balsam fir (*Abies balsamea*).

3.4 Wildland Fire Management

Wildfire is a natural and essential component of boreal and montane forests that plays an important role, along with forest insects and other disturbance factors, in creating and maintaining the shifting mosaic of stand ages and forest structure across large boreal landscapes that provide snowshoe hare and lynx habitats (Agee 2000, p. 47; Ruediger *et al.* 2000, pp. 1-3, 2-5, 7-6; ILBT 2013, p. 75). Wildfire creates and maintains lynx habitats by providing periodic vegetation disturbances that result in the spatial and temporal distribution of early-successional forest stands or patches within older stands featuring dense horizontal cover at ground and snow level. These stands/patches provide high-quality hare foraging habitat and typically support high hare densities, which in turn provide high-quality lynx foraging habitat. They are generated by (1) high-intensity, stand-replacing fires that result initially in removal of all or most vegetation, followed by regeneration of dense horizontal cover, or (2) low- or moderate-intensity fires that stimulate understory development in older stands without killing all the overstory, resulting in patches of dense horizontal cover within multi-story stands (Agee 2000, p. 53; Ruediger *et al.* 2000, p. 7-6). These habitats become most favorable for hares and lynx when regenerating conifers grow tall enough to protrude above the snow, providing cover and food for hares throughout the winter (ILBT 2013, pp. 10-12). They remain important as winter foraging habitat, which may be the most limiting habitat for lynx (Squires *et al.* 2010, p. 1656; ILBT 2013, pp. 17, 27), until they reach the stem-exclusion structural stage and self-pruning results in the loss of dense horizontal cover above the snow, or until another disturbance resets them to the stand-initiation structural stage (Agee 2000, pp. 62-71; Ruediger *et al.* 2000, p. 1-3; ILBT 2013, p. 27). The length of time to achieve favorable hare and lynx habitat after fire (or other vegetation disturbance) and the duration for which those conditions persist vary across the lynx range depending on soil and vegetation potential, temperature and precipitation patterns, topography, fire intensity, and perhaps other local conditions (Agee 2000, pp. 62-71; Ruediger *et al.* 2000, p. 2-5; ILBT 2013, pp. 27-29, 75). Generally, regenerating forests in the DPS range may begin providing winter hare habitat within 10-20 years after fire or other disturbance, with favorable conditions persisting for 20-30 years after that (Koehler and Aubry 1994, pp. 86-87;

Agee 2000, pp. 67-71; Fuller *et al.* 2007, p. 1985; McCann and Moen 2011, p. 515; Vashon *et al.* 2012, p. 15; ILBT 2013, pp. 28-29), although it may take longer, perhaps 35-40 years, for lynx habitat to recover in some parts of the range (e.g., Maletzke *in* Lynx SSA 2016a, p. 21).

Fire frequencies, sizes, intensities, and return intervals also vary across the range of the lynx and depend on local vegetation communities, climatic conditions, and topography (Agee 2000, pp. 47-56; Ruediger *et al.* 2000, p. 4-8; ILBT 2013, pp. 75-76). In lynx habitats, fire intensity is typically high and fire return intervals long but variable, with large areas affected by infrequent stand-replacing fires and, in mixed fire regimes, moderate- or low-intensity fires in the intervals between stand-replacing events (Agee 2000, pp. 49-54; Ruediger *et al.* 2000, pp. 4-8, 7-6). Within the DPS range, fire return intervals in the Great Lakes Region appear similar to those in the core of the lynx's range in the Canadian and Alaskan taiga (roughly 50-150 years), with longer return intervals in Western (150-300 years) and Northeastern (up to 500 years) forests (Agee 2000, pp. 52-53; ILBT 2013, pp. 75-76). Despite these long intervals, fire is the dominant natural disturbance mechanism in lynx habitats in the DPS range except in the Northeast, where insects and wind are more important (Agee 2000, p. 53).

Current Federal wildland fire management policy recognizes fire as a natural ecological process essential to the health and resilience of some forest systems, and it attempts to balance the ecological, social, and legal aspects of wildfire (USDA and USDI 2009, p. 6). However, the prior history of fire response was largely one of active suppression for most of the last century (Zimmerman and Bunnell 2000, p. 288; USDI *et al.* 2001, p. 1-1; USDA and USDI 2003, p. 3; 68 FR 40092; Calkin *et al.* 2015, pp. 1-3) which, combined with other land-use practices, dramatically altered fire regimes in some places and created conditions prone to larger and more severe fires (USDI *et al.* 2001, p. 1-2). Because of (1) fire's important role in creating and maintaining high-quality early-successional hare habitat in most lynx habitats in the contiguous United States, (2) the potential for fire suppression to alter this dynamic to the detriment of hares and lynx, and (3) the limited ability of land managers (at that time) to use fire to benefit hares and lynx, wildland fire management was identified as a "Lynx Risk Factor Affecting Lynx Productivity" (Ruediger *et al.* 2000, pp. 2-5, 5-2). To address these concerns, the authors developed objectives, standards, and guidelines for Federal land managers to restore fire's role in maintaining lynx habitats, attempt to mimic historical natural fire regimes, and integrate lynx habitat objectives into fire management plans (Ruediger *et al.* 2000, pp. 7-6 - 7-8). They also directed Federal land managers to evaluate whether fire suppression or other management practices had altered fire regimes and ecosystem function in potential lynx habitats and, where so, to use fire (naturally ignited fires or prescribed burns) as a tool to restore and maintain lynx habitat by creating or regenerating snowshoe hare habitat (Ruediger *et al.* 2000, p. 7-7).

In its 2000 listing rule and 2003 remanded determination, the Service recognized the potential for fire suppression to adversely affect lynx and hare habitats at local and regional scales, particularly in the Great Lakes Region, where fire suppression policies across land ownerships likely prevented fire from assuming its natural role in creating a landscape mosaic of vegetation communities and age classes (65 FR 16076; 68 FR 40095). In the Northeast, the Service concluded that the very long fire return intervals and maritime influence in lynx forest types

indicated that fire did not historically play a significant role in creating or maintaining lynx and hare habitats and thus fire suppression was unlikely to have affected lynx habitat (68 FR 40094). In the West, the Service concluded that the effects of fire suppression were likely lower in lynx forest types because of their typically long fire return intervals compared to lower and drier forest types (65 FR 16074; 68 FR 40093-94). Overall, the Service concluded that fire suppression did not represent a threat to lynx in the Northeast and was a low-magnitude threat in the Great Lakes, Southern Rockies, and Northern Rockies/Cascades (65 FR 16075-16076; 68 FR 40093-40098).

In response to the guidance provided in the LCAS, the USFS, when developing the NRLMD and the SRLA to amend forest plans to address lynx conservation (see 3.1.1), evaluated whether fire suppression had adversely affected potential lynx habitats on national forests in the Northern and Southern Rockies. The USFS concluded that many forests in potential lynx habitat are in Condition Class 1, which means they have not missed a fire cycle because large, stand-replacing fire only occurs every 100 to 200 years; the long fire return interval has not been affected to any large degree by more recent fire suppression as is the case in drier forests with short fire return intervals; and they are close to historical conditions (USFS 2007, pp. 18, 20; USFS 2008a, p. 11). In addition to the national forests covered by the NRLMD and SRLA (all national forests in the Northwestern Montana/Northeastern Idaho, GYA, and Western Colorado geographical units), the Superior National Forest, which accounts for 45 percent of the Northeastern Minnesota unit, revised its forest plan to adopt lynx conservation measures consistent with the LCAS (USFS 2004a, Appendix E). The Okanogan-Wenatchee National Forest in the North-central Washington unit is currently revising its management plan and continues to manage for lynx conservation in accordance with the LCAS, including direction to restore fire to its natural ecological role and to use it as a tool to restore and maintain hare and lynx habitats.

As described above in section 3.1.1, current Federal management on most USFS and BLM lands, in accordance with formally revised or amended management plans, includes limits on the proportion of lynx habitat within LAUs that can be in an unsuitable condition at any given time, including such conditions, usually temporary, created by wildfire. Although some exemptions and exceptions to these limits are permitted for activities to reduce fire risks to communities and infrastructure in the wildland-urban interface (WUI) or to achieve other resource benefits, even these potential impacts are limited on the larger landscape scale (USFWS 2007, p. 7). These conservation measures and the direction to use fire management (as well as timber harvest/vegetation management) as a tool to restore hare and lynx habitats and return to natural temporal and spatial patterns of fire disturbance, which were not in place when the DPS was listed, likely further reduce what was even then considered the low potential threat to lynx of past fire suppression activities. Based on the information above, we conclude that fire suppression and other fire management activities have not substantially impacted lynx and hare habitats in the DPS range and are unlikely to do so in the future.

However, warming temperatures attributed to climate change are reducing snowpack, causing earlier snowmelt and longer and more extensive droughts, resulting in longer wildfire seasons

and increased fire frequency, size, and intensity in boreal forests of the north and in boreal and montane forests in some parts of the DPS range (Weber and Flannigan 1997, entire; Stocks *et al.* 1998, entire; Gillett *et al.* 2004, entire; Kasischke and Turetsky 2006, entire; Soja *et al.* 2007, entire; Pierce *et al.* 2008, entire; Flannigan *et al.* 2009, entire; Krawchuk *et al.* 2009, entire; Le Goff *et al.* 2009, entire; Bergeron *et al.* 2010, entire; Salathe *et al.* 2010, entire; Abatzoglou 2011, entire; McKelvey *et al.* 2011, entire; Abatzoglou and Kolden 2013, entire; Pederson *et al.* 2013, p. 1815; Price *et al.* 2013, pp. 342-343, 352-354; Barbero *et al.* 2014, entire; Trenberth *et al.* 2014, entire; Barbero *et al.* 2015, entire; Jolly *et al.* 2015, entire; Lute *et al.* 2015, entire; USEPA 2015, entire; Lienard *et al.* 2016, entire; Littell *et al.* 2016, entire; Westerling 2016, entire; see also section 3.2 above). Increases in fire frequency and size have the potential to adversely affect lynx and hare habitats in the DPS range by rapidly converting large areas to the temporarily unsuitable stand-initiation successional stage, thus reducing the amount and altering the distribution of higher-quality habitats (ILBT 2013, p. 70). Although this would likely be a temporary impact, with burned areas subsequently regenerating into higher-quality habitat, it would likely reduce landscape-level hare densities and therefore lynx numbers, potentially compromising an area's ability to support a resident lynx population until burned habitats recover.

Because lynx habitats are naturally patchily-distributed and landscape-level hare densities already naturally marginal in many parts of the DPS range, it is possible that very large wildfires or many fires over a short time period could, perhaps in concert with other influencing factors, cause a shift in habitats in a given area from just barely capable of supporting a resident lynx population to no longer capable of doing so, resulting in extirpation. For example, as described in sections 2.3.2.2 and 4.2.4, large fires in Unit 4 during the past few decades have burned over a third of lynx habitat (Lewis 2016, pp. 4-6), increasing lynx home range size and reducing carrying capacity (Maletzke *in* Lynx SSA 2016, p. 21). If additional large fires occur in this unit before previously burned areas recover (10-40 years post-burn), carrying capacity and the lynx population would likely decline, further reducing the likelihood that resident lynx will persist (Lewis 2016, pp. 5-6; Lynx SSA Team 2016a, p. 44; also see sections 4.2.4 and 5.2.4). The loss of habitat resulting from these fires and its potential demographic impacts on the State's only resident lynx population contributed substantially to the WADFW's recent recommendation, and the State Fish and Wildlife Commission's decision, to uplist lynx from threatened to endangered under its State Endangered Species Program (Lewis 2016, entire; WAFWC 2016, p.3).

Wildfire frequency, size, and intensity have also increased in the Northwestern Montana/Northeastern Idaho geographic unit, where about 4,172 km² (1,611 mi²; over 15 percent of the unit) have burned in western Montana from 2000-2013 (Squires *in* Lynx SSA Team 2016a, p. 20). Large fires have also impacted lynx habitat in the Western Colorado geographic unit, where fire size, frequency, and intensity are expected to increase with climate change (Ivan *in* Lynx SSA Team 2016a, p. 23). As mentioned in section 2.3.2.2, large areas of the GYA unit were burned by the extensive wildfires of 1988. The extent to which those fires may have diminished lynx and hare habitats and contributed to the recent absence of resident lynx is uncertain, as is the potential for those burned areas to support high hare densities and resident lynx in the future. However, some burned areas may soon develop the dense horizontal conifer structure

favorable for hares and therefore for lynx foraging habitat, perhaps increasing the likelihood that they may support resident lynx in the near future.

Fire suppression was in the past thought to be a potential risk factor for lynx in the DPS range. However, given the trends discussed above and the likely continued increase in future fire activity related to projected continued climate warming, it may be necessary to reconsider whether fire suppression in some lynx habitats could benefit lynx by reducing the potential for extirpation of lynx populations, especially in places already affected by increased fire activity and those that are naturally only marginally capable of supporting resident lynx.

3.5 Habitat Loss and Fragmentation

Habitat loss for lynx is, generally, the conversion of boreal forest to another land use or vegetative cover. Fragmentation, which may involve permanent or temporary habitat loss, has been variously defined to describe a reduction of total area, increased isolation of patches, and reduced connectedness among patches of natural vegetation (Rolstad 1991; ILBT 2013, p. 76). “Patchiness” is sometimes used to refer to natural processes (Buskirk *et al.* 2000a, p. 85), whereas “fragmentation” refers to anthropogenic disruption of natural patterns. Boreal forest habitats in most parts of the DPS range are naturally patchy (ILBT 2013, p. 76) and marginal for both snowshoe hares and lynx compared to the northern cores of both species’ ranges. In the northern contiguous United States, boreal forest transitions to various types of northern hardwood forest in the Northeast and Great Lakes Region and to drier, more temperate montane forests in the West. The transitional nature of the boreal forest at its southern extent is believed (along with competition from other hare predators) to limit the numbers of both hares and lynx, preventing either from achieving densities comparable to those regularly achieved (except during the low of the hare population cycle) in the classic boreal forests in the cores of both species’ ranges in Canada and Alaska (Wolff 1980, pp. 123–128; Buehler and Keith 1982, pp. 24, 28; Koehler 1990a, p. 849; Koehler and Aubry 1994, p. 84; 79 FR 54790).

Forest loss and fragmentation are relatively low in the DPS range compared to other forested regions in the United States (Heilman *et al.* 2002, p. 416). Since 2000 in the western United States, land uses associated with residential development, roads, and highway traffic have resulted in a 4.5 percent (20,000 km² [7,722 mi²]) loss in forest area, and continued expansion of residential development will likely reduce forested patches by another 1.2 percent percent by 2030 (Theobald *et al.* 2011, entire). Human-caused fragmentation in the forested western landscape resulted in a decline of weighted mean patch size from roughly 35,000 km² (13,514 mi²) to 3,200 km² (1,236 mi²) from natural to current conditions, but models predict relatively small declines in the size of forested patches over the next 30 years (Theobald *et al.* 2011, p. 2451). In the eastern United States, nearly half or more of the natural forest was cleared in the past 3 centuries, but as agriculture and settlement relocated westward and some eastern farmlands were abandoned, eastern forest cover rebounded (Williams 1989; Smith *et al.* 2005). Similarly, a large portion of Minnesota’s forests was cleared in the last century and, although overall forest cover has rebounded, the forested area in northern Minnesota has decreased 4 percent since 1977 (Miles *et al.* 2007, p. 22). Future trends portend increased human population

and declining forestland in the United States (Haynes 2003), but whether and to what extent forest conversion will affect boreal forest habitat in the DPS is uncertain.

Effects of Fragmentation - Canada lynx seem to be flexible in their response to habitat fragmentation, whereas closely related species, such as bobcats and Iberian lynx, are sensitive to habitat fragmentation (Ferrerias 2001; Crooks 2002). In southern Ontario, Hornseth *et al.* (2014, pp. 8-9) demonstrated that lynx exhibited a wide range of responses to habitat alteration. In general, lynx responded most positively to areas having greater than 50 percent suitable habitat and generally avoided areas having less than 30 percent suitable habitat. However, lynx showed no sensitivity to the degree of forest fragmentation in areas of high or low suitable habitat.

In the DPS range, lynx achieve highest densities in landscapes having a high percentage of large, contiguous patches of high-quality hare habitat (Simons 2009; Simons-Legaard *et al.* 2013). Throughout the DPS range, landscapes with more contiguous boreal forest habitat support more snowshoe hares than fragmented landscapes, and lynx select habitats that improve their foraging opportunities (Moen *et al.* 2008; Vashon *et al.* 2008a; Simons 2009; Fuller and Harrison 2010; Squires *et al.* 2010; Lewis *et al.* 2011, p. 565; ILBT 2013, p. 77). During winter, coarse-scale habitat selection by lynx in Maine maximized their access to snowshoe hares (Fuller and Harrison 2010; ILBT 2013, p. 77). In Montana, lynx similarly selected habitat patches that supported snowshoe hares and in winter avoided recent clearcuts or other open patches (Squires *et al.* 2010; ILBT 2013, p. 77). Several other studies documented lynx avoidance of large openings, especially during winter, probably because such habitats are rarely used by hares and would not, therefore, attract foraging lynx (Koehler 1990a; Mowat *et al.* 2000; von Kienast 2003; Maletzke 2004; Squires and Ruggiero 2007; ILBT 2013, p. 77). Koehler (1990a) suggested that lynx movements and habitat use patterns could be altered temporarily by vegetation management that creates large distances (> 100 m [328 ft]) to forested cover (ILBT 2013, p. 77).

Throughout the northern part of their range, snowshoe hares are found in vast areas of boreal forest interspersed with occasional bogs and fens and water that are less preferred. Conversely, southern hare populations (including most in the DPS range) occur primarily in insular patches of suitable habitat set amidst large areas of less-preferred habitats (Wolff 1980; Keith *et al.* 1993). This disparity has led a number of biologists to speculate that habitat fragmentation ultimately may be responsible for the non-cycling nature of snowshoe hare populations in southern Canada and the northern contiguous United States (Dolbeer and Clark 1975; Buehler and Keith 1982; Keith *et al.* 1993; Strohm and Tyson 2009). Wolff (1980, 1981) described the mechanism by which a fragmented habitat might dampen or eliminate cyclic population fluctuations. The patchy distribution and generally lower densities of hares in many parts of the contiguous United States require lynx in most areas of the DPS range to maintain larger home ranges than lynx in the core of the species' range (Mowat *et al.* 2000, pp. 265, 277–278). Larger home ranges likely require more energy output associated with greater foraging effort to acquire adequate food (Apps 2000, p. 364) and may expose lynx to increased risk of predation and

other mortality factors such as roads and trapping. At some point, landscape hare densities become too low, making some areas incapable of supporting lynx.

Snow, also an important component of lynx habitat (79 FR 54809), can be patchily-distributed, variable and unpredictable from year to year, and affected by local topography, water bodies, and climate gradients. Snow depth (Hoving *et al.* 2005; Peers *et al.* 2013, entire) and persistence (Gonzalez *et al.* 2007) are believed to give lynx a competitive advantage over generalist predators in the contiguous United States. The snow environment in much of the DPS range is patchy and marginal in both space and time for snowshoe hares and lynx. Too little snow or crusting conditions may favor potential competitors and predators like bobcat, fisher, and coyotes. High elevations may provide snow conditions that favor lynx, whereas lower elevations may favor conditions for competitors. Snow conditions that provide lynx a competitive advantage over other terrestrial hare predators are most consistent in the high-elevation regions of the western United States, although snow alone does not constitute lynx habitat (i.e., many places receive sufficient snow but lack other features lynx need, typically adequate hare densities). Lynx likely have a competitive advantage at higher elevations in the DPS in the winter, but not in summer months when potential competitors have increased access to all habitats. Snow conditions are less consistent in the East. For example, lake-effect snow from Lake Superior can increase snow depth and duration in northeastern Minnesota in some years but not in others. The Gulf of Maine has the reverse effect, and its warming influence reduces snow depth and duration inland. Distribution models by Hoving (2001, p. 74) indicate that eastern Maine has extensive areas of boreal forest, but they do not achieve snowfall conditions associated with lynx presence in other parts of the state, and lynx are rarely found there.

Naturally patchy forests and those fragmented by humans may exacerbate competition between lynx and other predators (Buskirk *et al.* 2000a, entire). Forest patchiness, fragmentation, and competition are strongly linked because vegetation mosaics in landscapes provide high-quality environments for generalist species such as the bobcat, red fox, and coyote (Goodrich and Buskirk 1995; Buskirk *et al.* 2000a, p. 84), and generalist predators tend to dominate the predator guild in patchy or fragmented landscapes (Oehler and Litvaitis 1996). Hares fluctuate less dramatically in the southern part of the lynx range, thus there is more competition for a limited resource and exploitation competition could be inflicted by generalists (e.g., coyotes) and other predators (Buskirk *et al.* 2000a, p. 95). Snowshoe hares in the south are concentrated in isolated patches of suitable habitat and subject to predation by a suite of generalist predators (e.g., Litvaitis *et al.* 1985; Sievert and Keith 1985; Keith *et al.* 1993; Cox *et al.* 1997). Keith *et al.* (1993) found that an extremely high predation rate on hares living in high-quality habitats seemed to be driving the changes in distribution and abundance in a snowshoe hare population in Wisconsin, rather than predation on naturally dispersing individuals. In that study, predation pressure on hare populations occupying small (< 7 ha [< 17 ac]) patches of preferred habitat was so severe that 3 of the 5 populations under investigation were extirpated in the course of the 3-year study. Fragmentation exacerbates the effect of predation by allowing carnivores to concentrate their hunting efforts on small patches of habitat used by their preferred prey instead of preying disproportionately on dispersing individuals (Wirsing *et al.* 2002, p. 170). In predator-

rich landscapes characteristic of the DPS, this can result in intense predation and competition for a limited prey resource.

Landscape features further fragment hare and lynx habitat. In the western geographic units, potentially suitable boreal forests and appropriate snow conditions occur in relatively narrow elevational bands in the Cascade and Northern and Southern Rocky Mountains (McKelvey *et al.* 2000a, pp. 243-246). Thus, lynx habitats are naturally fragmented by topography and vegetation gradients. These “islands” of habitat can be extensive (e.g., the Okanogan in Washington or most of northwestern Montana) or smaller and relatively isolated (e.g., the Garnet Range in western Montana) depending on topography and precipitation patterns. Some of these areas of boreal forest are separated by unsuitable habitats in the low valleys (e.g., sage flats, urban corridors, agricultural lands) or by snow regimes (e.g. snow shadows) that may discourage lynx dispersal between habitat patches (although verified records of lynx in many parts of the contiguous United States and long-distance dispersal of lynx released in Colorado demonstrate that lynx at least occasionally navigate such habitats). In some western parts of the DPS range, lynx habitat is also fragmented by rugged, high elevation terrain (Carroll *et al.* 2001, p. 976). In most areas of the DPS, including Maine and Minnesota where there is little topography, lynx travel through a “matrix” of less suitable forested areas as they move between areas of higher-quality habitat. Large rivers are unlikely to fragment habitat as lynx readily swim across large bodies of water (Feierabend and Kielland 2014, entire) or cross them on ice in the winter (Koen *et al.* 2015).

As described above, both lynx and hares are influenced by the spatial arrangement of preferred habitat. Lynx populations are clearly most viable in areas having extensive and relatively unfragmented boreal forest habitats with large patches of high-quality foraging (hare) habitat and persistent deep, unconsolidated snow. Similarly, individual lynx have the smallest home ranges and greatest survival and productivity in landscapes that have extensive, large patches of habitat in combination with deep, fluffy snow. The factors described above create a naturally patchy distribution of high-quality lynx habitat throughout much of the DPS range, resulting in generally lower reproductive output and a more tenuous conservation status for lynx in many parts of the DPS relative to those in Canada and Alaska (Buskirk *et al.* 2000a, p. 95). Thus, human activities, described below, that increase boreal forest fragmentation may further reduce the quality of lynx habitat that is already naturally marginal throughout much of the DPS range, perhaps reducing the likelihood that resident lynx populations will persist.

Anthropogenic Sources of Fragmentation - Human activities can exacerbate the naturally-patchy habitat that is typical throughout much of the DPS range. Anthropogenic activities such as forest management, development, and highways alter natural landscape patterns. They cumulatively can reduce the total area of habitat, diminish the quality of habitat, increase the isolation of habitat patches, and impair the ability of lynx and other wildlife to effectively move between patches of habitat. Anthropogenic fragmentation may be permanent, for example by converting forest habitat to residential, industrial, or agricultural purposes, or temporary, for example by conducting forest management but allowing trees and shrubs to regrow. Habitat

fragmentation (both natural and anthropogenic) increases the risk of extirpation of small lynx populations.

Human-caused fragmentation of the already naturally patchy pattern of lynx habitat in the contiguous United States can affect lynx by reducing their prey base and increasing the energetic costs of using habitat within their home ranges. Buskirk *et al.* (2000a) identified direct effects of fragmentation on lynx to include creation of openings that potentially increase access by competing carnivores, increasing the edge between early-successional habitat and other habitats, and changes in the structural complexities and amounts of seral forests within the landscape. At some point, landscape-scale fragmentation can make patches of foraging habitat too small and too distant from each other to be effectively accessed by lynx as part of their home range. Maintaining a mosaic of large (> 40 ha [100 ac]) patches of young to old stands in patterns that are representative of natural ecological processes and disturbance regimes would be conducive to long-term conservation of lynx (ILBT 2013, p. 77).

Roads, development, climate change, and forest management fragment snowshoe hare and lynx habitat in the DPS. We know little about how hare and lynx respond to these anthropomorphic changes to their habitat, which requires additional research (Murray *et al.* 2008, p. 1464; Squires *et al.* 2013, p. 194). In the next decades, southern lynx populations will likely incur further habitat loss and fragmentation from these and other factors. Changes in habitat, prey base, and perhaps competitor guild will likely impact lynx populations in the DPS and in southern Canada.

Roads - Paved highways fragment lynx habitat. They surround large areas of lynx habitat in Minnesota and northern Maine. In the West, they typically follow natural features such as rivers, valleys, and mountain passes that may have high value for lynx in providing habitat or connectivity. Nonetheless, the density of paved roads is generally low in most lynx habitat in the DPS range. Various studies have documented lynx crossing highways. A male lynx in western Wyoming was documented to have successfully crossed several 2-lane highways during exploratory movements (Squires and Oakleaf 2005). However, in Alberta, Canada, high road densities, human activity, and associated developments appeared to reduce the habitat quality based on decreased occupancy by lynx (Bayne *et al.* 2008). Apps *et al.* (2007) found lynx were 13 times less likely to cross the Trans-Canada Highway (a 4-lane highway) relative to random expectation, but only 2.2 and 3.1 times less likely to cross smaller 2-lane highways (93 and 1A, respectively). In southeastern British Columbia, lynx avoided crossing highways within their home ranges (Apps, 2000). Squires *et al.* 2013 (p. 194) documented 44 radio-collared lynx with home ranges within an 8 km buffer of 2-lane highways; however, only 12 of these individuals crossed the highway. Paved highways also pose a risk of direct mortality to lynx and may inhibit lynx movement between previously connected habitats. If lynx avoid crossing some highways, this could lead to a loss of effective habitat within a home range and reduced interaction within a local population (Apps *et al.* 2007). Lynx and other carnivores may avoid using habitat adjacent to highways, or become intimidated by highway traffic when attempting to cross (Gibeau and Heuer 1996; Forman and Alexander 1998).

Carnivores are especially vulnerable to highway-caused mortality in areas with dense and high traffic volume roadways (Clevenger *et al.* 2001). As the standard of roads increases from single-lane gravel to 2-lane or 4-lane highways, traffic volumes and the degree of impact are expected to increase. Walpole *et al.* (2012, p. 770) found that small logging roads with low traffic volume had no effect on lynx distribution, and lynx in Nova Scotia followed road edges for considerable distances (Parker 1981, p. 229). In Maine, lynx occasionally travel on unplowed logging roads during winter, but these roads and their associated edge habitat were selected against within home ranges (Fuller *et al.* 2007, p. 1983). Lynx killed fewer hares near logging roads in Maine likely because hare density was lower there than in adjacent un-roaded habitats (Fuller *et al.* 2007, p. 1985; Fuller and Harrison 2010, p. 1274) or possibly because of increased potential for interactions with generalist competitors such as coyotes (Fuller *et al.* 2007, p. 1985). In Minnesota, Moen *et al.* (2010b) found that lynx selected for roads during long-distance movements. Although roads may not be essential to these movements, lynx appeared to benefit energetically from the use of these linear features. Squires *et al.* (2008) reported that lynx denned farther from all roads compared to random expectation.

Four-lane highways, such as the interstate highway system, commonly have fences on both sides, service roads, parallel railroads or power lines, and impediments like "Jersey barriers" that make successful crossing more difficult, or impossible, for wildlife (ILBT 2013, p. 78). Alexander *et al.* (2005) suggested traffic volumes between 3,000 and 5,000 vehicles per day may be the threshold above which successful crossings by carnivores are impeded. In Colorado, lynx successfully and repeatedly crossed major highways, including I-70 (Ivan 2011c; 2011d; 2012). Colorado lynx crossed 2-lane highways an average of 0.6 times per day and more frequently during dusk and at night when traffic volume was lower (Baigas *et al.* 2017, p. 204). They also crossed 4-lane highways (I-70), especially in forested areas under large, elevated bridges that spanned streams (Baigas *et al.* 2017, p. 204).

Between 2000 and 2015, 54 lynx were reported to have been killed on roads (both paved and unpaved) in Maine (Vashon, MDIFW, *unpubl. data*), 9 in Minnesota (and 2 hit by trains; USFWS 2016b, *unpubl. data*), 1 in Idaho, and 5 in Montana (USFWS 2016c, *unpubl. data*). Between 1995 and 2011, 15 lynx were reported killed on British Columbia highways (British Columbia Wildlife Accident Reporting System 2012, as cited in ILBT 2013, p. 78). Most of these mortalities are on higher-speed paved highways. However, in Maine, about 41 percent (22 of 54) were killed on dirt logging roads with low traffic volumes and lower speed limits. In Minnesota, 2 lynx were killed on backcountry railroads and 2 on unpaved forest roads. Backcountry roads also provide human access into lynx habitat where incidental trapping or illegal shooting can occur.

Translocated lynx may be more vulnerable to road mortality than resident lynx (Brocke *et al.* 1991, p. 308), because they often move extensively after their release and are unfamiliar with their surroundings (ILBT 2013, p. 78). In the Adirondack Mountains of New York, an attempt to reintroduce lynx failed and 18 of 37 documented mortalities (among 83 lynx released over 3 years; Brocke *et al.* 1993, p. 1) were attributed to road kills (Brocke *et al.* 1991, p. 308; ILBT 2013, p. 78). Over a 7-year period in Colorado, 13 of 102 documented mortalities of translocated lynx were the result of vehicle collisions on highways (Devineau *et al.* 2010, p.

528). Traffic volumes on those Colorado highways were estimated to range from about 2,300 to > 25,000 vehicles per day (USFWS 2016c, *unpubl. data*, p. 1).

In summary, roads of all sizes may have direct (e.g., habitat loss and fragmentation, vehicle collisions) as well as indirect effects to lynx. The latter may include increasing human access, potentially resulting in increased incidental trapping and illegal shooting; creating edge habitats that may promote co-occurrence with potential competitors like coyotes and bobcats (Bayne *et al.* 2008, p. 1195); reducing prey densities; and influencing lynx behavior, both detrimentally (avoidance) and beneficially (energetic savings during long-distance movements). Although potential adverse impacts of roads in lynx habitats likely outweigh any potential benefits, thus far population-level impacts of roads have not been demonstrated among DPS lynx populations.

Vegetation Management - As described above in section 3.3, forest management can further fragment boreal forest in the northern contiguous United States, potentially affecting habitat suitability for both snowshoe hares and lynx. Large-scale forest fragmentation or maturation can be detrimental to snowshoe hares because both can cause hares to become increasingly restricted to remaining small patches with adequate cover, where higher predation rates from a variety of carnivores tend to increase local hare extinction risk (Wolff 1981; Keith *et al.* 1993; Wirsing *et al.* 2002; see also Barbour and Litvaitis 1993, entire). Although forest management can benefit lynx if it creates, maintains, or restores a shifting mosaic of high-quality habitat, it can also be detrimental if it fragments habitat into small, widely-spaced parcels. Changes to vegetation structure can influence lynx movements; in Montana, fragmentation from forest thinning decreased the probability of lynx movements across the forested landscape (Squires *et al.* 2013, p. 192). Lynx in the Northern Rockies also seem sensitive to changes in forest structure and avoid large forest openings like recent clearcuts and thinned areas, particularly in winter (Koehler, 1990a; Squires *et al.* 2010). Modeling in Maine suggests that the shift from clear-cutting to partial harvesting will likely increase the number of patches of high-quality hare habitat but greatly reduce the size of patches and increase their isolation (Simons-Legaard *et al.* 2016, pp. 5-6), thus diminishing landscape habitat quality for lynx. See section 3.3 for further discussion of vegetation management as a potential source of habitat fragmentation.

Residential and Commercial Development - Residential and commercial development is increasing on private forest lands. Increased traffic and urbanization are projected for the Northern Rockies (Hansen *et al.* 2002) and Maine (also see section 5.2.1). It is uncertain to what degree lynx can tolerate habitat fragmentation from roads and clearing forest for development, and how human and pet activity associated with development may affect lynx use of habitats. Some anecdotal information suggests that lynx are quite tolerant of humans, although given differences in individuals and contexts, a variety of behavioral responses to human presence may be expected (Staples 1995, Mowat *et al.* 2000). The degree to which residential development and associated roads reduce connectivity of mesocarnivore populations (including lynx) likely depends on the physical design of highway improvements, the surrounding environmental features, the density of increased urbanization, and the increased traffic volume (Clevenger and Waltho, 2005; Grilo *et al.* 2009).

Ski area development also results in permanent habitat loss and fragmentation. One ski run is often separated from the next only by small inter-trail forest islands. Ski runs often are intermixed with other open areas such as open or gladed bowls, rock outcrops, or barren tundra ridges. Ski resorts that are built or expanded in lynx habitat may impact lynx by removing forest cover, reducing the snowshoe hare prey base, and creating or increasing human disturbance in or near linkage areas. There is limited information on lynx behavior and habitat use in and around ski areas. Lynx have been known to incorporate smaller ski resorts within their home ranges, but may not utilize the large resorts. Preliminary information from an ongoing study in Colorado suggests that some recreational use may be compatible, but lynx may avoid some areas with concentrated recreation use. In some areas, lynx habitat may be limited and concentrated in the ski area development footprint (ILBT 2013, p. 55). More than 50 ski areas exist throughout the range of the lynx in the contiguous United States (ILBT 2013, pp. 82-83). Most ski areas are located on north-facing slopes, where ample snow conditions provide for extended ski/snowboard recreational seasons. In the western states, many of these landscapes feature spruce-fir forests. While ski resorts occupy a small proportion of the landscape, spruce-fir forests provide important habitat for snowshoe hares and lynx at the southern extent of their range. In winter, alpine and Nordic skiing and snowboarding are the primary uses. Most of these resorts offer year-round recreation, with summer activities typically including hiking and mountain biking. Despite concerns regarding ski-area impacts to lynx, they have affected only a tiny fraction of potential lynx habitats in the DPS range, and no population-level effects of ski areas or related recreation activities have been demonstrated for DPS lynx populations.

Mineral Extraction – Mining and oil and gas exploration and production activities occur primarily within the western units of the DPS although there is increased interest in mining in the Minnesota and Maine units. Lynx habitats may be lost and fragmented as a result of mining, similar to other development: loss of boreal forest; construction of roads, railroads, and transmission lines; and increased human access and disturbance where lynx occur. In the West, for example in the Wyoming Range (Unit 5), extensive oil and coal bed methane development can affect large areas of landscape (e.g., 1 well per 2-4 ha (5-10 ac) and could diminish potential lynx habitat in some areas. Open pit and subsurface mines can affect from tens to thousands of hectares of habitat. To reduce effects of mineral development, land exchanges are sometimes implemented to consolidate private land ownership of the surface above a deposit to be mined. Depending on the lands exchanged, this could retain lynx habitat in public ownership. Surface deposits of minerals and gravel for forest road construction are excavated within some lynx areas and vary from a single truck load to tens of acres. Although mining and oil and gas development can result in loss and fragmentation of lynx habitats, thus far, effects to DPS lynx populations have not been demonstrated.

Wind Energy - Wind energy development and associated transmission lines are increasing across the nation and could affect lynx habitats. Facilities are often located on ridge tops or other areas exposed to consistent wind. Construction of wind facilities, including access roads, clearing for turbines, and transmission lines, may result in loss of lynx habitat and increased fragmentation from permanent forest clearings. Noise and human activity associated with the construction and operation of wind facilities could disturb or displace lynx from important

habitats. Effects would likely continue through the life of the project, which may exceed 20 years. Wind energy development has occurred in some areas of the lynx DPS but has effected relatively small amounts of lynx habitat. Despite being a potential source of additional habitat loss and fragmentation, there is no information to suggest that wind energy development has had population-level effects on lynx in the DPS range.

Utility Corridors - Utility corridors contain developments such as overhead or buried powerlines and gas pipelines, and often are located within or adjacent to existing road rights-of-way. Utility corridors potentially could have short- or long-term impacts to lynx habitats, depending on location, type, vegetation clearing standards, and frequency of maintenance. Those that are extensively cleared of vegetation and maintained in grass or herbaceous vegetation likely equate to a permanent habitat loss. When associated with highways and railroads, utility corridors may further widen rights-of-way. Utility corridors can facilitate human access into previously remote areas potentially exposing lynx to increased trapping, illegal shooting, or other human disturbance. In most instances, naturally-vegetated utility corridors are less than 300 m (984 ft) wide and would not be expected to block lynx movements. Despite being a potential source of additional habitat loss and fragmentation, there is no information to suggest that impacts from utility corridors have had population-level effects on lynx in the DPS range.

Agriculture - Agricultural activity currently is not expanding in lynx habitat areas and has decreased in some parts of the DPS range. For example, the amount of farmland in northern Maine has declined by over 75 percent, from over 1.2 million ha (3 million ac) in the late 1800s, to about 283,000 ha (700,000 ac) early this century (Ahn *et al.* 2002, p. 8). Most of the current farming is in northeastern Maine, where it fragments the forested landscape corridor between core habitats in northern Maine and western New Brunswick. However, lynx have been documented dispersing through this landscape (J. Vashon, Maine Department of Inland Fisheries and Wildlife, *unpubl. data*). Forest clearing for agriculture also may have contributed (along with increasing road densities and an expansion in coyote distribution) to the recent contraction in the southern part of lynx range in eastern Alberta (Bayne *et al.* 2008, p. 1195). Overall, agricultural activities occur at very low levels within potential lynx habitats in the DPS range, and no impacts to DPS lynx populations have been demonstrated.

Habitat Loss and Fragmentation in Corridor Areas Connecting Lynx Populations in the DPS with Adjacent Populations in Canada - Lynx conservation in the contiguous United States is thought to depend in part on maintaining connectivity with habitat areas and lynx populations in Canada. Maintaining connectivity for lynx may become increasingly difficult because of climate change and other anthropogenic influences, as evidenced by reduced connectivity for other boreal species (van Oort *et al.* 2011). Potential corridors have been identified in the northern Rockies (Squires *et al.* 2013, entire). There are likely broad forested corridors with suitable dispersal habitat connecting core habitats in Maine to southern Quebec and northern New Brunswick, and northern Minnesota to southern Ontario. Given the perceived importance of lynx immigration from Canada to the persistence of the DPS (FR 68 40076– 40101; Squires *et al.* 2013, p. 187), roads and other forms of habitat loss and fragmentation that may impede lynx movements in the border regions of Canada and the United States are of concern.

Summary - Although lynx responses to forest management and forest roads are relatively well understood (e.g., Simons-Legaard *et al.* 2016, entire; sections above), their response to other human activity and types of development remain poorly understood. Nearly all studies of lynx in North America occurred in remote areas where human activity and development are minimal. In more developed areas of the DPS range, lynx may have to balance selection for prey density against mortality risk from humans. For example, in a developed landscape in Norway, Eurasian lynx demonstrated a trade-off in habitat selection, avoiding areas near human development despite high prey (roe deer, *Capreolus capreolus*) densities, and instead selecting areas with intermediate prey abundance and lower levels of human disturbance (Basille *et al.* 2009, pp. 687-690). Their occurrence in areas having intermediate human occupancy (Basille *et al.* 2009, p. 687) confirms their ability to live in relatively human-modified habitats. Because lynx and snowshoe hares in North America are not typically associated with human development, it is uncertain whether Canada lynx would make similar trade-offs between prey density and risks associated human activity.

Overall, most lynx habitats in the DPS range are naturally fragmented, which limits the abundance and density of both hares and lynx. The largest source of anthropogenic fragmentation throughout the DPS range is vegetation management (timber harvest and related silvicultural treatments), which has thus far benefitted lynx in northern Maine by creating optimal hare (and thus lynx foraging) habitat. In other geographic units, there have likely been localized adverse (and potentially some beneficial) impacts of vegetation management to lynx habitats and perhaps individual lynx. However, we find no evidence that habitat loss and fragmentation from forest management or other anthropogenic activities have had population-level negative consequences for resident lynx in the DPS range or resulted in extirpation of lynx from areas that previously supported persistent resident populations. That said, many parts of the DPS range seem naturally only marginally capable of supporting resident lynx populations, and it is possible that relatively low levels of anthropogenic habitat loss and fragmentation, in addition to natural fragmentation, could diminish landscape-level hare densities to the point that resident lynx populations may be unable to persist.

Chapter 4: Current Conditions

In this chapter, we present our understanding, based on the best available scientific information, including the professional judgment and opinions of lynx experts, of the current status of the lynx DPS in terms of redundancy, representation, and resiliency. We then provide brief summaries of the current conditions in each geographic unit, followed by a more detailed evaluation of the status of lynx populations and habitats and the factors currently believed to influence them in each unit. Where appropriate, we compare our current understanding to what was known or believed when the DPS was listed under the ESA in 2000 and to our understanding of historical conditions.

4.1 Summary of Current Conditions DPS-wide

Because of the limitations and uncertainty in the historical records of lynx occurrence in the contiguous United States (described above in section 2.3.2.1), it is difficult to compare the current distribution and status of resident lynx populations in the DPS with what may have been the historical condition (but see evaluation in section 2.3.2.2). However, research and surveys over the last 2 decades have significantly improved our understanding of the current distribution, habitats, and the status of resident populations compared to what was known when the DPS was listed in 2000. For example, although we knew there were some resident lynx in Maine (Unit 1), we lacked information on the quality and distribution of lynx and hare habitats and the potential number of lynx. We now know this unit currently has large areas of high-quality habitat created by the regeneration of areas of extensive clear-cutting in the 1970s and 1980s in response to a large spruce budworm outbreak, that there are probably more lynx in Maine now than was likely under historical natural disturbance regimes and habitat distributions, and that currently this unit probably supports the largest resident lynx population in the DPS. Similarly, when the DPS was listed, we were uncertain whether Minnesota (Unit 2) supported a resident population. We now know that a persistent population occupies the northeastern corner of the state. Research also suggests that lynx and habitats in the western United States (Units 3, 4, 5, and 6) are naturally less abundant and more patchily-distributed than was thought at the time of listing, and several areas thought to have historically supported small resident populations currently do not (the GYA [Unit 5], the Garnet Mountains in western Montana [Unit 3], and the Kettle Mountains of northeastern Washington). We also know that recent extensive wildfires in north-central Washington (Unit 4) have substantially reduced (probably temporarily) the amount of high-quality lynx habitat and likely caused a decline in lynx numbers there. Finally, as a result of the release of 218 Canadian and Alaskan lynx from 1999-2006 and the subsequent survival and reproduction of some of these lynx and some of their offspring, resident lynx currently occupy parts of western Colorado (Unit 6), although the current number of lynx there is uncertain.

With regard to redundancy, defined as the ability of the DPS to withstand catastrophic events, we find that the current broad distribution of resident lynx populations in large, geographically discrete areas makes the DPS invulnerable to extirpation caused by a single catastrophic event. The DPS range currently spans the northern contiguous states from Maine to Washington and south along the Rocky Mountains to southern Colorado. Resident breeding lynx populations currently occupy 5 of the 6 geographic units (all but the GYA; fig. 1). Of the 5 occupied units, 4 are larger than 20,000 km² (7,722 mi²), and the other (North-central Washington) is over 5,000 km² (1,931 mi²; see tables 2 and 3). Our analyses and lynx expert input indicate no single catastrophic event that could result in the functional extirpation (loss of the ability to support resident lynx populations) of the entire DPS and, further, no or a very low likelihood of functional extirpation of any of the individual geographic units caused by a single catastrophic event (Lynx SSA Team 2016a, p. 56).

Because we lack evidence that resident lynx populations have been lost from any other large geographic areas in the contiguous United States, it also seems that redundancy in the DPS

has not been meaningfully diminished from historical levels. That is, the loss of resident lynx populations in the DPS, to the extent suggested by verified historical records, was likely in areas peripheral to the geographic units that currently support resident lynx (e.g., northern New Hampshire [McKelvey *et al.* 2000a, pp. 212-214], the Kettle/Wedge area of northeastern Washington [Koehler *et al.* 2008, p. 1523; Lewis 2016, pp. 1-2], Isle Royale in Lake Superior [Licht *et al.* 2015, entire]). Any small populations that were lost were not in large, discrete geographic units that would have represented substantially greater redundancy in the contiguous United States. The implications of the potential recent loss of resident lynx in the GYA for the redundancy of the DPS are unclear. The historical record and recent research show that the GYA has supported resident lynx. However, it is unclear whether the area consistently supported a resident breeding population over time or whether it naturally supported resident lynx only some of the time (“winked on” in a metapopulation sense) when habitat conditions and hare densities were favorable, and at other times, when habitats and hare densities were less favorable, it did not support resident lynx (“winked off” in a metapopulation sense). Given the protected conservation status of millions of acres in the GYA unit (Yellowstone and Grand Teton national parks; all or parts of the Absaroka-Beartooth, Bridger, Gros Ventre, Lee Metcalf, Northern Absaroka, Teton, and Washakie Wildernesses), its apparent recent inability to support resident lynx may be a reflection of naturally marginal and patchy habitats and relatively low hare abundance in much of the unit, resulting in only an intermittent ability of this unit to support resident lynx. If so, the contribution of the GYA to redundancy within the DPS is questionable.

Representation, defined as the ability of the DPS to adapt to changing environmental conditions, is characterized by the breadth of genetic and ecological diversity within and among populations (Lynx SSA Team 2016a, p. 25). Lynx experts and geneticists indicated high rates of dispersal and gene flow and, therefore, generally low levels of genetic differentiation across most of the species’ range, including the DPS (Lynx SSA Team 2016a, pp. 12-14, 55-56). Although hybridization with bobcats has been documented in the DPS (in Maine and Minnesota), it is not considered a substantial current threat to the DPS (Lynx SSA Team 2016a, p. 13). Further, despite differences in forest community types and other habitat parameters (e.g., topography and elevations) lynx across the range of the DPS occupy a similarly narrow and specialized ecological niche defined by specific vegetation structure, snow conditions, and the abundance of a single prey species. Therefore, lynx likely have little ability to adapt to changing environmental conditions (i.e., shift to other forest habitats, snow conditions, or primary prey species). However, although some small populations may have become extirpated recently, resident lynx in the DPS remain broadly distributed across the range of ecological settings that seems to have supported them historically in the contiguous United States. Because there are no indications of current threats to the genetic health or adaptive capacity of lynx populations in the DPS, we find that the current level of representation does not appear to represent a decrease from historical conditions.

Resiliency, the ability to withstand stochastic disturbance events, is currently exhibited in the lynx DPS by the persistence of individual lynx populations and their broad distribution across the geographic scope of the DPS. However, because we lack reliable estimates of the sizes and trends of most lynx populations in the DPS, we are unable to use these parameters to evaluate

the current resiliency of individual populations or geographic units. Although some demographic data (survival, reproductive rates) are available for each geographic unit (see table 4), they were collected using different methods, at different times, and for different intervals, and possibly at different points in hare population cycles or fluctuations and, therefore, do not provide a consistent measure of resiliency. Efforts to understand resiliency within the DPS are also confounded by the metapopulation structure thought to govern lynx populations at the southern margin of their continental range, which suggests that some populations may be naturally ephemeral (i.e., “winked on” when conditions are favorable; “winked off” when conditions are not favorable). The related uncertainty about the extent to which DPS populations may rely on cyclic immigration of lynx from Canada during population irruptions and the ambiguity in the historical record that limits our understanding of the relative persistence of lynx in various geographical areas also limit our ability to characterize, rank, or model the relative contribution of each geographic area to the resiliency of the DPS.

Despite uncertainties and data deficiencies, qualitative factors provide some hints about current relative resiliency among some geographic areas or parts of them. For example, in Maine, lynx have demonstrated resiliency by responding positively to substantial anthropogenic increases in the amount and distribution of high-quality foraging habitat. Conversely, the current apparent absence of resident lynx in the GYA (Unit 5) and in the Garnet Mountains of Unit 3 may indicate the lower level of resiliency expected among small and relatively more isolated populations. The persistence of lynx in north-central Washington (Unit 4) despite the substantial recent wildfire-mediated loss of habitat suggests resiliency in that population; however, the post-fires increase in home range size and likely decrease in lynx numbers may indicate the population is currently less resilient (less able to persist if additional or similar habitat losses occur) than it was previously. Overall, the apparent long-term (historical and current) persistence of resident lynx populations in at least 4 of the 6 geographic units (Units 1-4), and the absence of reliable information indicating that the current distribution and relative abundance of resident lynx are substantially reduced from historical conditions, suggest historical and recent resiliency of lynx populations in the DPS.

In summary, the lynx DPS currently exhibits redundancy sufficient to preclude extirpation as a result of catastrophic events. The genetic health and ecological diversity expressed across the DPS range likewise suggest the recent and current maintenance of representation. The long-term persistence and broad geographical distribution of lynx populations in 4 of the 6 geographic units also suggests historical and recent resiliency in the DPS, although the potential recent extirpation of several small populations may be an indication of declining resiliency in those places.

4.1.1 Summaries of Current Conditions in Each Geographic Unit

Unit 1 - Northern Maine: This geographic unit encompasses the northern hardwood and spruce-fir (Acadian) forest in roughly the northern half of Maine. Resident lynx in this unit represent the southern periphery of a larger and highly resilient population (Harrison 2017, p. 3) that also occupies southern Quebec (where trapping is legal) and northern New Brunswick

(where lynx are a provincially-endangered species and harvest is prohibited). Although the actual number of resident lynx in this unit is unknown, the MDIFW believes this unit currently may be capable of supporting 750-1,000 lynx based on estimates of habitat distribution and lynx home range sizes (Vashon *et al.* 2012, pp. 87-91), which would make it the largest population in the DPS. This is many more resident lynx than likely occurred historically and many more than were suspected to occur in this unit when the DPS was listed, and it is the result of extensive clearcutting and herbicide application to salvage spruce-fir and encourage softwood regeneration following a severe spruce budworm outbreak in the 1970s and 1980s (Hoving *et al.* 2004; Vashon *et al.* 2008b; Simons 2009, pp. 122-165). Those past treatments have created the current extensive distribution of young, regenerating softwood stands that provide optimal hare foraging habitat. Lynx responded to these conditions with high survival and reproduction, small home ranges, and the highest densities documented in the DPS. Historically, under a more natural disturbance regime, Maine typically had a greater proportion of mature forest and, therefore a patchier distribution of high-quality habitat that likely supported a smaller lynx population that may have been more dependent on immigration from Canada. State forestry regulations passed in 1989 caused landowners to shift to various forms of partial harvesting that have resulted in lower landscape hare densities across much of the unit. Hare populations do not seem to cycle in this region, but hare density estimates from 2008-2015 declined by over 50 percent compared to estimates from 2001-2006. Reproduction and adult survival declined in the low-hare environment after 2006, although kitten survival remained high. Unlike other DPS units, lynx habitat in northern Maine occurs nearly entirely on private, industrial forest lands, most of which lack long-term commitments to lynx management. The majority of private lands in this unit are now owned by investment companies seeking to diversify income from their investments, which could result in forest practices less likely to maintain or conserve hare and lynx habitat. Other potential stressors to lynx in this unit include incidental trapping, road mortality, large-scale wind energy development, residential and resort development, and parcelization of forestlands from rapid turnover in investment company landowners. Another spruce budworm outbreak may be imminent, and forestry response by investment landowners is uncertain. Climate change is a concern because average annual snowfall and duration are currently at the minimum thresholds believed necessary to give lynx a competitive advantage over bobcats and other mesocarnivores. Although lynx regularly occur outside this unit in southeastern and southwestern Maine, and small numbers of reproducing lynx have also been documented recently in northern New Hampshire and northern Vermont, the ability of some of these peripheral areas to support persistent breeding populations is questionable. However, recent telemetry data in Maine suggest that resident lynx are expanding both east and south of the Northern Maine Geographic Unit, with home range maintenance and reproduction documented in both areas, which previously were considered outside the area capable of supporting resident lynx (Vashon 2017, *pers. comm.*).

Unit 2 - Northeastern Minnesota: This geographic unit contains a mix of upland conifer and hardwood interspersed with lowland conifer, alder (*Alnus* spp.) or willow (*Salix* spp.) shrub swamps, and black spruce (*Picea mariana*) or tamarack (*Larix laricina*) bogs. Despite uncertainty when the DPS was listed, it has become apparent that a reproducing resident population of roughly 50 to 200 lynx exists in northeastern Minnesota. This unit is directly

connected to lynx habitats and populations in Canada, and lynx in this unit likely represent the southern extent of a larger cross-border population, most of which occurs in Ontario, where trapping of lynx is legal. Lynx in Minnesota select regenerating forest dominated by conifer with extensive forest edge; lynx beds (resting and hunting) and kill sites are associated with regenerating and mixed forest (Burdett 2008, p. 57). Hare densities in parts of northeastern Minnesota appear to be sufficient to support a viable lynx population and are highest in regenerating forests (McCann and Moen 2011, p. 513). The Superior National Forest continues to manage lynx habitats in accordance with its 2004 Forest Plan, which includes measures to minimize several risk factors and promote lynx conservation on the forest. Management of lynx habitat on State and private lands is voluntary and lacks long-term commitments to lynx management. Factors affecting current conditions in this unit primarily include forestry management, roads, and incidental trapping; other factors that could potentially impact resident lynx in this unit include mining development, snow compaction related to winter recreation, competition with bobcats, and lynx-bobcat hybridization. Since 2000, 45 lynx mortalities have been documented in Minnesota from unknown causes (16), incidental trapping (11), vehicle collisions (9 on roads and 2 on railroads), and illegal shooting (7). Six lynx radio-collared in Minnesota died after traveling north into Ontario, 4 from legal trapping/hunting, and 2 from unknown causes; some of these mortalities occurred years after the lynx was last located in Minnesota, indicating survival of Minnesota lynx in Ontario for extended periods is possible.

Unit 3 - Northwestern Montana/Northeastern Idaho: The historical and current sizes of the resident lynx population in this unit are unknown, but it is thought currently to be capable of supporting 200-300 lynx home ranges. Habitats capable of supporting resident lynx in this unit are naturally patchier and less-broadly distributed (Squires *et al.* 2006a, pp. 46-47; Squires *et al.* 2013, p. 191), and lynx therefore naturally rarer, than was thought when the DPS was listed (ILBT 2013, p. 23; Jackson *in* Lynx SSA Team 2016a, p. 12). Minor genetic differences suggest 3 subpopulations in the northwest (Purcell Mountains), central (Seeley Lake), and southern (Garnet Mountains) parts of the unit. No lynx were detected in the Garnet Range from 2011 to 2015, prompting concerns about the potential loss of the small resident population (perhaps 7-10 lynx) documented there in the mid-1980s and again recently from 2002 to 2010. However, whether this absence indicates the extirpation of a previously persistent resident population or the temporary loss of an historically ephemeral population is uncertain. A single lynx was verified in the Garnet Range in February 2016, indicating that natural recolonization of the area is possible; however, subsequent surveys have failed to detect that lynx or other lynx, and there currently remains no evidence of lynx residency in this mountain range (Lieberg 2017, *pers. comm.*). Most (about 90 percent) of this unit is managed to conserve and restore lynx and hare habitats, including on Federal, State, Tribal, and some private lands. Past timber harvest and associated management (e.g., thinning, road construction, fire suppression) appear to have had localized impacts but not to have diminished the unit's ability to support resident lynx, with habitats in the Garnet Range being a possible exception (see 4.2.3 below). The size, frequency, and intensity of wildfires in this unit have increased over the past several decades, likely in response to climate warming, but population-level impacts to lynx have not been documented. Whether (and if so to what extent) other climate-mediated factors have influenced the current condition of lynx populations or habitats in this unit are also unknown. Regulations prohibit lynx

trapping and require measures to reduce the likelihood of trapping lynx incidentally when legally trapping other species. Hare densities have not been estimated broadly throughout the unit but appear to be low or marginal even in what is considered the highest-quality habitat, suggesting that even small decreases in habitat quality/hare densities could influence its continued ability to support resident lynx. The role of past and recent immigration in maintaining the demographic and genetic health of current lynx populations in this unit is unknown, but peaks in cyclic lynx numbers in Canada have declined, especially when compared to the unprecedented irruptions of the early 1960s and 1970s, and there is no evidence of significant immigration into this unit since then.

Unit 4 – North-central Washington: This geographic unit encompasses extensive boreal forest vegetation types and is directly connected to lynx habitats and populations in British Columbia. It represents about 58 percent of the Okanogan Lynx Management Zone (LMZ) designated by the WADNR. Historical and current resident lynx numbers in northern Washington are unknown, but recent habitat and home range analyses for the larger Okanogan LMZ (summarized in Lewis 2016) suggest that this geographic unit may have been capable of supporting about 50 lynx prior to extensive wildfires over the past 2-3 decades (85-90 lynx in the entire LMZ). Those fires affected over a third of the LMZ, led to increased home range size, and may have reduced the carrying capacity of this unit to perhaps 30 lynx currently (50-55 in the entire LMZ). Additional extensive wildfire activity in the northern part of this unit in 2017 may result in further reduction of carrying capacity. The recent increases in wildfire frequency, size, and intensity in lynx habitat in this unit may have been influenced by climate change (Westerling *et al.* 2006, pp. 942-943). Burned habitats are expected to regenerate back into suitable lynx habitat, but this may take 10-40 years. However, additional wildfire activity in this unit before previously burned areas recover could substantially reduce the viability of the lynx population in this geographic unit (see section 5.2.4). Because of these habitat impacts and remaining stressors to lynx, the Washington Department of Fish and Wildlife recently submitted, and the State Fish and Wildlife Commission adopted, a proposal to uplist lynx from threatened to endangered within the State. Hare densities in Washington are generally at the low end of the range thought necessary to support lynx persistence. The Okanogan-Wenatchee and Colville National Forests, which administer more than 90 percent of lynx habitat in Washington, continue to manage in accordance with the LCAS. Additionally, the WADNR, which manages approximately 4 percent of lynx habitat in Washington, developed a Lynx Habitat Management Plan in 1996, which was updated in 2006 and is also largely based on the LCAS. The Kettle Range to the east of this unit was suspected to have supported a small (likely fewer than 20 individuals) resident population until about 30 years ago when over-trapping compounded by habitat changes may have resulted in its extirpation (Stinson 2001, p. 13; Koehler *et al.* 2008, p.1523). Potential impediments to lynx movement between the Kettle Range and the Cascades and British Columbia may make natural recolonization of the Kettle Range unlikely.

Unit 5 - Greater Yellowstone Area (GYA): There are no reliable estimates of current or historical lynx numbers in this unit but, given its naturally-fragmented potential habitat, generally low hare densities, and the paucity of verified records, it appears unlikely this unit ever supported a large resident population, and it is possible that this unit historically supported resident lynx only

ephemerally. No lynx have been verified in this unit since 2010, but whether this indicates the extirpation of a small but previously persistent resident population or the temporary loss of an historically ephemeral population is uncertain. Over 97 percent of this unit consists of Federal lands that are currently managed to conserve and restore lynx and hare habitats. Past timber harvest and associated management (thinning, road construction, fire suppression) appear to have had localized impacts but not to have diminished the unit's ability to support resident lynx. The size and intensity of wildfires have increased over the past several decades, predominantly in the northern half of the unit (including the large fires of 1988 in Yellowstone National Park) and likely in response to climate warming, but impacts to lynx are uncertain. Whether (and if so to what extent) other climate-mediated factors have influenced the current condition of lynx populations or habitats in this unit are also unknown. Snow conditions currently appear to be adequate, with most of this geographic unit modeled to have a 95 percent probability of providing snow cover conditions supportive of lynx presence (Gonzalez *et al.* 2007, p. 12). Hare densities were very low in most of Yellowstone National Park but high in parts of the Bridger-Teton National Forest in the southern half of the unit. The role of past and recent immigration in maintaining the demographic and genetic health of lynx populations in this unit is unknown. This unit lacks direct connectivity to other lynx populations, and there is only anecdotal evidence that irruptions of lynx from Canada resulted historically in immigration into this unit. At least 9 lynx released in Colorado dispersed northward into this unit and some temporarily occupied home ranges in areas used previously by native resident lynx, but there is no evidence of long-term occupancy or reproduction by these lynx.

Unit 6 - Western Colorado: The current and historical numbers of resident lynx numbers in this unit are unknown, but CPW lynx biologists believe it currently could support 100-250 lynx as a result of the 1999-2006 release of 218 lynx from Canada and Alaska. Released lynx had high survival but the proportion of females producing kittens and kitten survival were low. This unit is not directly connected to lynx populations in Canada, and it does not appear to have received immigrant lynx during the historically large irruptions of the early 1960s and early 1970s. Since 1996, 2 unprecedentedly large bark beetle epidemics have affected about 16,200 km² (6,255 mi²) of spruce-fir and lodgepole pine forests in Colorado, including much of the lynx habitat in this unit. Additionally, the 2013 West Fork Complex fire impacted more than 400 km² (154 mi²) of lynx habitat in the San Juan Mountains. Beetle outbreaks do not appear to have negatively impacted hares, and hare numbers may increase in affected areas as succession progresses; however, they have negatively impacted red squirrels, an important alternate prey species for lynx in this unit. Areas affected by beetles that contained multi-story stand conditions likely continue to provide habitat to support snowshoe hares and lynx. Areas affected by fire may require 20 years or more, and in some areas considerably longer, to recover to a point where the stands will again support snowshoe hares. Large-scale monitoring efforts in the San Juans documented continued lynx occupancy during 2010-11, 2014-15, and 2015-2016, and it is reasonably likely that lynx continue to occur in all national forests within the State of Colorado. Snowshoe hare habitat is naturally patchily-distributed in this geographic unit, which limits hare abundance. Because the majority (90 percent) of potential lynx habitat in Colorado is under Federal land management, actions occurring on other ownerships are unlikely to result in significant impacts to lynx habitat within this unit. The USFS manages over 85 percent of the

lynx habitat in this unit, providing conservation through the SRLA. However, regulatory mechanisms for the conservation of lynx are lacking on approximately 3,159 km² (1,220 mi²; over 12 percent) of this unit, including lynx habitats on some BLM and some non-Federal lands.

Table 4. Summary of current conditions in 6 geographic units within the DPS range¹.

	Unit 1 - Northern ME	Unit 2 - Northeastern MN	Unit 3 - Northwestern MT, Northeastern ID	Unit 4 - North-central WA	Unit 5 - Greater Yellowstone Area	Unit 6 - Western CO
Unit Size (km²)	28,909	21,101	26,997	5,176	23,687	25,294
Percent of Unit in Conservation Ownership (i.e., Federal, State, Tribal, Other Conservation Org.)	10 - 15	75 - 90	> 95	> 90	> 95	> 90
Connectivity to Lynx Populations/Habitats in Canada	Directly connected to lynx habitats/ populations in s. Quebec and n. New Brunswick; evidence of natural movement, but rates of immigration/emigration unknown	Directly connected to lynx habitats/ populations in s. Ontario; evidence of natural movement, but rates of immigration/emigration unknown	Directly connected to lynx habitats/ populations in s. Alberta and s. British Columbia; evidence of natural movement, but rates of immigration/emigration unknown	Directly connected to lynx habitats/ populations in s. British Columbia; evidence of natural movement, but rates of immigration/emigration unknown	No direct connection; rates of immigration/emigration unknown	No direct connection; rates of immigration/emigration unknown; long-distance dispersal (emigration) documented to many western states and to Canada
Home Range Size (Adult Female, km²)	25-33	17 - 21	43 - 115	37 - 91	50 (1 female, 3 years)	75
Productivity – Percent Females with Kittens	89% (high hares); 30% (low hares);	100%	83% (Purcells); 61% (Seeley Lake)	100% (2 females)	Few data	24%
Productivity - Litter Size	2.74 (high hares); 2.25 (low hares)	3.3	2.95 (Purcells); 2.24 (Seeley Lake)	2.25 (2 females)	3.0 (1 female, 2 years)	2.75
Average Annual Adult Survival Rate	0.80 (high hares); 0.71 (low hares)	0.75 - 1.00	0.85 (Purcells); 0.75 (Seeley Lake)	0.86	Few data	0.93 (in Core Release Area [CRA]); 0.82 (out of CRA)
Kitten Survival Rate	0.78 (high hares); 0.89 (low hares)	No estimate; recruitment thought low	0.58 (Seeley Lake)	0.12 (7 of 8 kittens died in 1st year)	No estimate; no evidence of kitten survival to independence	0.23
Lambda (Annual Rate of Population Change)	1.05 (1.16, high hares, 6 yrs; 0.88, low hares, 4 yrs)	No estimate	1.16 (Purcells, 4 yrs); 0.92 (Seeley Lake, 8 yrs)	No estimate	No estimate	0.93 - 1.08

¹Estimators used to calculate home range size are provided in table 3.

4.2 Current Conditions - Detailed Descriptions by Geographic Unit

4.2.1 Unit 1 - Northern Maine

Unit Description: This geographic unit encompasses approximately 28,909 km² (11,162 mi²) of northern hardwood and spruce-fir forest (the Acadian forest) in northern Maine that has been designated as critical habitat for lynx (79 FR 54823-54828). Land ownership in this unit is about 90 percent private, 7 percent State (primarily Baxter State Park), 1 percent Federal (the newly-designated Katahdin Woods and Waters National Monument and Appalachian Trail Corridor), and 1 percent Tribal (Passamaquoddy Tribe, Penobscot Indian Nation). Almost all private lands are intensively managed for commercial forest (timber and pulp) products. This unit is directly connected to lynx habitats and populations in southern Quebec and northern New Brunswick. Lynx in this unit represent the southern extent of a larger cross-border population, most of which

occurs in the Gaspé region of southern Quebec and northern New Brunswick (Ray *et al.* 2002, pp. 17-20) and which is geographically isolated by the St. Lawrence River from lynx populations in central Quebec (120 km [75 mi] north of Maine). Lynx populations in Maine and eastern Canada are also geographically isolated from other lynx populations on the island of Newfoundland (900 km [559 mi] northeast of Maine), and on Cape Breton Island, Nova Scotia (650 km [404 mi] east of Maine; Koen *et al.* 2015, entire; Prentice *et al.* 2017, entire). Lynx in Maine are also isolated from other DPS populations, the closest of which is in northeastern Minnesota, about 1,610 km (1,000 mi) west of this unit.

Lynx regularly occur outside this unit and recently have been documented in smaller areas of similar habitat in southeastern and southwestern Maine, northern New Hampshire, and the northeastern corner of Vermont (see below). Occasional lynx reproduction has been documented recently in New Hampshire and Vermont, but these areas are not thought to support persistent breeding populations and are likely incapable of doing so (see below). Climate in this region is characterized by warm summers and some of the coldest temperatures and highest snowfalls in the eastern United States; a function of latitude, elevation, and distance from the ocean. The average terrain rises in northern Maine to 305-457 m (1,000-1,500 ft) with mountain peaks, particularly in western Maine, northern New Hampshire, and Vermont, from 914-1,524 m (3,000-5,000 ft). Average annual precipitation is currently 104 cm (41 in), with greatest precipitation in winter in the form of snow (average total snowfall is 228-280 cm (90 - 110 in), with higher amounts at the highest elevations. Snow duration is about 5 months (mid-November through mid-April).

New Hampshire - Potential habitat in northern New Hampshire is limited (Hoving 2001, p. 59), and the few habitat patches that support lynx in New Hampshire are much smaller than those in northern Maine (Litvaitis and Tash 2005, fig. 2 and p. A-298; Robinson 2006, fig. 3.3, p. 99). Hoving estimated approximately 1,000 km² (386 mi²) of potential habitat having a greater than 50 percent probability of being occupied by lynx (68 FR 40086). Litvaitis and Tash (2005, p. A-298) estimated that New Hampshire contains about 888 km² (343 mi²) of potential Canada lynx habitat. Historical lynx occurrence in New Hampshire included Coos and northern Carroll and Grafton counties (i.e., White Mountain National Forest; Siegler and Jorgensen 1971; Silver 1974; Hoving *et al.* 2003). The majority of lynx records in northern New Hampshire over the past 10 years have occurred in the vicinity of Pittsburg on the 101-km² (39-mi²) Connecticut Lakes Natural Area (CLNA), which is owned and managed by New Hampshire Fish and Game, and on surrounding habitat owned and managed by the Connecticut Lakes Timber Company under a conservation easement held by the State (Kilborn 2015, App. A, pp. 42-43). The CLNA, under a conservation easement, includes a 61-km² (23-mi²) area that will be allowed to mature to a climax forest type which is contained within what is considered core lynx habitat. The area will potentially provide good denning habitat but will likely restrict the amount of snowshoe hare habitat in the foreseeable future. Current conditions are in a transition state, and portions of the core area currently support higher densities of snowshoe hare because of past forest management (Kilborn 2015, App. A pp. 42-43). Regional-scale modeling suggests that a high component of deciduous forest and insufficient snow conditions in New Hampshire make it

unlikely to support a persistent, viable lynx population over time (Hoving *et al.* 2005, pp. 739, 749).

Vermont – Recent modeling indicates that the Nulhegan River Basin contains Vermont's best lynx habitat (Farrell 2012). The 530-km² (205-mi²) area is approximately 20 percent Federal (Nulhegan National Wildlife Refuge), 17 percent State (Vermont Department of Natural Resources), and 63 percent private commercial timber lands (with conservation easement). Vermont does not appear to have historically supported a persistent resident lynx population and, despite several recent verified records of lynx presence and evidence of limited reproduction (see section 2.3.2.2), it is unlikely to do so in the future because of the patchy and limited amount of potential habitat, climate change (decreasing snow), trends toward hardwood management, and increasing human disturbance (Vermont Fish and Wildlife 2015, Appendix A5 p. 127).

Habitat Description: Most lynx occurrence records in this unit are found within the broadly described "Mixed Forest-Coniferous Forest-Tundra" cover type (68 FR 40086). This habitat type occurs along the northern Appalachian Mountain range from southeastern Quebec, northern New Brunswick, and northern and western Maine, south through northern New Hampshire. This area is part of the Acadian Forest Region (Rowe 1972, p. 112-129) representing a transition between northern boreal spruce and balsam fir and southern temperate deciduous forests (Seymour and Hunter 1992, pp. 3-4). This forest type becomes naturally fragmented and begins to diminish to the south and west, with a disjunct segment running north-south through Vermont and a patch in the Adirondacks of northern New York (McKelvey *et al.* 2000a, pp. 248-250). Patches of boreal forest in New Hampshire, Vermont, and New York are more highly fragmented and smaller than in northern Maine. These more southerly forests also contain a higher proportion of northern hardwood and are believed to lack an adequate conifer component needed to produce sufficient snowshoe hare densities to consistently support resident lynx populations (Hoving *et al.* 2005, p. 749; Carroll 2007, p. 1100). Northern Maine is characterized by low-relief, hilly terrain, but with some higher elevations in the Katahdin Highlands and in western Maine. Higher elevations support a predominantly coniferous forest (white, red, and black spruce; balsam fir; eastern white pine [*Pinus strobus*]) intermixed with northern hardwoods (red maple, aspen, paper [white] birch, sugar maple [*Acer saccharum*], beech [*Fagus spp.*], and yellow birch [*Betula alleghaniensis*]). Lowland areas include spruce-fir flats interspersed with peatlands (black spruce, tamarack).

In this unit, lynx are most strongly associated with stands of regenerating sapling spruce-fir forest supporting high hare densities (Homyack 2003, p. 53; Fuller and Harrison 2005, p. 716, Vashon *et al.* 2008b, p. 1492; Scott 2009, pp. 24, 32, 36-44). Most current high-quality stands in this unit are the result of landscape-level clearcutting in the 1970s and 1980s (see Habitat Status, below). Regenerating stands used by lynx typically develop 15-30 years after timber harvest (Hoving *et al.* 2004, p. 291) or other disturbance (e.g., periodic spruce budworm defoliation), are characterized by high stem density and dense horizontal cover within 1 m (3 ft) of the ground (Robinson 2006 pp. 26-36, Scott 2009, pp. 81-93; Fuller and Harrison 2010, p.

1276-1278; Vashon *et al.* 2012, p. 15), and support the highest snowshoe hare densities (Homyack 2003, p. 63; Fuller and Harrison 2005, pp. 716, 719; Vashon *et al.* 2005a, pp. 10–11).

At the stand scale, lynx in northwestern Maine selected older (11- to 26-year-old), tall (4.6- to 7.3-m [15- to 24-ft]) softwood-dominated (spruce and fir) regenerating clearcut stands, adjacent older (11- to 21-year-old) partially harvested stands in close proximity to clearcut stands (Fuller *et al.* 2007, pp. 1980, 1983–1985), and mature conifer stands (Simons-Legaard *et al.* 2013, p. 568) where hares are more accessible. During winter, lynx primarily selected tall (4.4–7.3 m [15–24 ft]) regenerating clearcuts and established partially harvested stands that were 11–21 years post-harvest (Fuller *et al.* 2007, pp. 1984-1985). Lynx selected against mature second-growth stands (> 40 years old), short (3.4–4.3 m [11–14 ft]) regenerating clear-cut or partially harvested stands < 10 years post-harvest, and roads and road edges (Fuller *et al.* 2007, pp. 1980, 1983-1985). Research of year-round habitat use yielded similar results, with lynx preferentially using conifer-dominated sapling stands that were 3.4–7.3 m (11–24 ft) in height and supported high densities of snowshoe hares (Vashon *et al.* 2008b, pp. 1492-1495). At the home range scale, lynx select landscapes having extensive regenerating conifer forest, but also with some mature conifer forest (Simons-Legaard *et al.* 2013, pp. 572–573). Lynx tended to forage in areas with intermediate to high hare densities, where hares were more accessible to lynx compared to the densest (short regenerating) stands (Fuller and Harrison 2010, pp. 1276-1278). Lynx may select partially harvested and mature conifer stands in close proximity to clearcut stands because of increased ease of travel and access to hares along the extensive edges of the densest, high-quality (regenerating clear-cut) hare habitats (Simons-Legaard *et al.* 2013, p. 574). Lynx are more likely to occur in large landscapes having a high percentage (> 27 percent) of regenerating forest, and less likely to occur in landscapes with very recent clearcuts or extensive partial harvest (Hoving *et al.* 2004, pp. 291–292; Simons-Legaard *et al.* 2013, entire).

Denning habitat included various types of coarse woody debris including blowdown, deadfalls, and root wads. In northern Maine, nearly half (12 of 26) of natal dens occurred in conifer-dominated sapling stands, and 6 dens were found in mature or mixed multi-story forest stands dominated by conifers (Organ *et al.* 2008, pp. 1515-1517).

In general, landscape scale and home range scale habitat selection by lynx on commercial forest lands reinforces the importance of dense regenerating conifer forest along with a component of mature conifers (Hoving *et al.* 2004, p. 286; Vashon *et al.* 2008b, pp. 1494-1495; Simons 2009, pp. 64-110; Simons-Legaard *et al.* 2013, p. 568). Simons-Legaard *et al.* (2013, p. 573) found the probability of lynx occurrence was > 50 percent where landscape hare densities were > 0.74 hares/ha (0.39 hares/ac) and there was > 10 percent mature conifer forest. No lynx maintained home ranges in landscapes with hare densities < 0.5 hares/ha (0.2 hares/ac). At a landscape scale, lynx habitat selection did not differ between sexes; however, at a home range scale, males tended to use more mature forest dominated by conifers than females, and both male and female lynx tended to avoid mature forests that had a high deciduous component (Vashon *et al.* 2008b, pp. 1492-1493). Based on these observations, Simons-Legaard *et al.* (2013, pp. 574-576) recommended maintaining landscape hare densities of > 0.5 hares/ha (0.2

hares/ac) and a minimum of 27 percent high-quality hare habitat within 100-km² areas to conserve lynx.

Habitat Status: As elsewhere in the DPS, boreal spruce-fir forest habitats in the Northern Maine Unit are naturally patchily-distributed and intermixed with northern hardwoods, riparian areas, and peatlands. USFS forest inventory data indicate that over 16,000 km² (6,178 mi²) of forestland are classified as spruce-fir in Aroostook, Penobscot, Piscataquis, and Somerset Counties in northern Maine (McWilliams *et al.* 2005, p. 122), although not all of this forest type is in areas occupied by lynx. Currently, most of the high-quality hare and lynx habitat in northern Maine is the result of extensive landscape-scale clearcut timber harvesting in response to a spruce budworm outbreak in the 1970s–1980s (Hoving *et al.* 2004, p. 291; Simons 2009, pp. 64, 218). Many of these clearcuts were also treated with herbicides to promote conifer regeneration by suppressing deciduous tree species. After salvage harvest of the affected trees, a portion of the area was sprayed with herbicide to reduce deciduous competition (Scott 2009, pp. 7, 14). The resulting vegetation was dominated by balsam fir and red or black spruce (Scott 2009, p. 60). This created favorable habitat conditions for snowshoe hares and lynx. Habitat conditions for hares and lynx in the unit improved from the late-1980s to present, benefitting from stand-replacing salvage harvests during the last budworm outbreak (Simons 2009, pp. 122-229; Simons-Legaard *et al.* 2016, entire). During this time period, the percentage of forestland with an average landscape hare density greater than 0.5 hares/ha (0.2 hares/ac) increased 400 percent (Simons-Legaard *et al.* 2016, p. 7). Both the current amount of high-quality habitat and the lynx population in Maine are likely larger than occurred prior to European settlement, when a relatively smaller proportion of the forest was typically in an early successional stage (Lorimer 1977, entire; Vashon *et al.* 2012, pp. 45, 56).

In the Northeast prior to European settlement, lynx habitat was created and maintained by frequent, small-scale forest gap dynamic events and infrequent, large-scale stand-replacing forest disturbances (Seymour *et al.* 2002, pp. 359-365; Lorimer and White 2003, pp. 54-58). Historically, the natural disturbance regime (fires, windthrow, insect outbreaks) resulted in smaller, more frequent disturbances and long intervals between larger disturbances; thus, high-quality lynx foraging habitat in northern Maine was probably typically much less abundant and less broadly-distributed than it is today. Large, stand-replacing events (fire, wind and ice storms, insect outbreaks) are rare (intervals of several hundred to several thousand years) and highly variable in size (Seymour *et al.* 2002, entire; Lorimer and White 2003, pp. 50, 54, 59). Spruce budworm, spruce beetle, beech bark disease, and sugar maple defoliators have been important influences affecting forest landscape patterns (McNab and Avers 1994, Chapter 14). The frequency and intensity of spruce budworm outbreaks, the most likely insect to affect lynx habitat, have been highly variable in Maine and eastern Canada in recent centuries (Blais 1983, entire). Although, high-elevation boreal forests often exhibit dense, regenerating conifer (resulting from a wind-throw phenomenon known as fir-waves [Sprugel 1976, entire]), hare densities are believed to be low in these areas (Siren *et al.* 2015, entire). In this geographic area, wildfire is less significant as a natural agent of disturbance. The typical fire regime is infrequent surface fires in the dormant season in the hardwood forests, and slightly more frequent but long-interval fires in conifer forests (Kilgore and Heinselman 1990, entire; Seymour

et al. 2002, pp. 359-365, Lorimer and White 2003, p. 59). For the past several decades, early successional forests and lynx habitat in northern Maine, New Brunswick, and southern Quebec have been created almost exclusively by forest management (Lorimer and White 2003, pp. 42-43).

In a roughly 14,500-km² (5,598-mi²) area in northern Maine (about half of the Northern Maine geographic unit), Simons-Legaard (2016, p. 9-10) estimated that 3,845 km² (1,485 mi²; nearly 27 percent) of the forested landscape was comprised of spruce-fir in a young, regenerating stand condition that provide high-quality hare habitat. This habitat is similar to, and contiguous with, forested areas in Quebec and New Brunswick that support lynx (Hoving *et al.* 2005, pp. 740-741). The current range of lynx in this unit is associated with areas of deep snowfall, extensive forested landscapes, and areas having a high proportion of regenerating conifer-dominated forest that had previously been clearcut and treated with herbicides to suppress hardwoods (Homyack 2003, p. 2; Hoving *et al.* 2004, p. 287).

Snowshoe hare populations in Maine do not seem to cycle at 10-year intervals, but they have experienced a period of higher (1995-2005) and lower (2006 to present) densities (Scott 2009, pp. 1-44; Vashon *et al.* 2012, p. 14; Harrison *et al.* 2016, entire). Prior to 2006, several estimates of hare densities in the highest-quality regenerating conifer or mixed forest averaged 1.9 to 2.1 hares/ha (0.8 to 0.9 hares/ac; Homyack *et al.* 2007, p. 8; Robinson 2006, p. 26). After 2006, hare densities declined by about half in all stand types and have remained at these lower levels (Scott 2009, p. 109; D. Harrison, Univ. Maine, *unpubl. data*). Similar trends were observed in the Gaspé Region of Quebec (Assells *et al.* 2007, entire). In New Hampshire in 1990, hare densities in dense, regenerating spruce-fir stands were about 0.5 hares/ha (0.2 hares/ac) at low and high elevations (Brocke *et al.* 1993, p. 61). More recently, Siren *et al.* (2015) reported lower densities in New Hampshire (0.25 to 0.36 hares/ha [0.1 to 0.15 hares/ac]) that are unlikely to support lynx persistence in both montane and lowland spruce-fir. Densities in high elevation areas (krumholtz, stunted spruce-fir) were only 0.19 to 0.28 hares/ha (0.08 to 0.11 hares/ac), also unlikely to support lynx persistence. Comparable hare density data are not available for Vermont.

Currently, the amount and distribution of high-quality habitat are likely at historically high levels, but this habitat has peaked and high-quality lynx habitat is projected to decline in the near future (Simons-Legaard *et al.* 2016, pp. 140-163, 202-218). In response to the widespread clearcutting in the 1970s and 1980s, Maine passed the Forest Practices Act in 1989, which regulated clearcutting. Since then, various forms of partial harvesting have replaced clearcutting as the predominant form of forest management in northern Maine. Partially harvested stands (e.g., selection harvest, shelterwood harvest, overstory removal) have a wide range of residual stand conditions, but many have lower conifer stem densities and higher hardwood density than regenerating clearcuts (Robinson 2006, p. 29). On average, partially harvested stands support about 50 percent of the hare densities observed in regenerating clearcuts (Robinson 2006, p. 26-27). Over 95 percent of cutting that occurs now in northern Maine is partial harvesting compared to 59 percent in 1988 (Scott 2009, p. 8; Simons 2009, pp.45-47, 69-71; Simons-Legaard *et al.* 2013). This new cutting regime results in lower landscape densities of snowshoe

hares (Fuller 1999; Homyack 2003; Robinson 2006; Scott 2009). Another consequence of partial harvesting is that a much greater acreage needs to be cut annually to attain similar harvest volume (as compared to clearcutting). Annual harvest rates have increased from about 40,000 ha (100,000 acres) per year (before the Forest Practices Act) to over 200,000 ha (500,000 acres) per year (after the Act). Thus, 28 years after the Maine Forest Practices Act, much of the forested landscape in northern Maine has been partially harvested.

Unlike Federal lands, there is no requirement that private landowners comply with lynx management guidelines, and a Federal nexus for review of forestry projects rarely exists. Furthermore, there continues to be high turnover in forest land ownership (Hagan *et al.* 2005; Ippoliti and Nadeau-Drillen 2006) and little funding to provide incentives or to work with private landowners. As of 2005, there were 23 landowners in northern Maine with land holdings in excess of 40,000 ha (100,000 ac) including the State, Federal government (White Mountain National Forest south of lynx range), a conservation group (The Nature Conservancy), 2 tribes (Penobscot Indian Nation and Passamaquoddy Tribe with much land south of lynx range) and 18 private forest landowners (Ippoliti and Nadeau-Drillen 2006, p. 13).

Although long-term, binding land management commitments are generally lacking in the northern Maine unit, several landowners have made short-term commitments to conserving lynx habitat. In 2003, Congress passed the Healthy Forest Restoration Act. Title V of this Act designates a Healthy Forest Reserve Program (HFRP) with objectives to: (1) promote the recovery of threatened and endangered species, (2) improve biodiversity, and (3) enhance carbon sequestration. In 2006, Congress provided the first funding for the HFRP, and Maine, was 1 of several pilot States to receive funding through its Natural Resources Conservation Service (NRCS) State office. Based on a successful pilot program, in 2008, the HFRP was reauthorized as part of the Farm Bill, and in 2010, NRCS published a final rule in the Federal Register (75 FR 6539) amending regulations for the HFRP based on provisions amended by the bill. In 2006 and 2007, the NRCS offered the HFRP to landowners in the proposed Canada lynx critical habitat unit in Maine to promote development of Canada lynx forest management plans. Since that time 4 private landowners, The Nature Conservancy, the Passamaquoddy Tribe, Merriweather LLC, and Katahdin Forestlands successfully enrolled in the program. Collectively, these land ownerships comprised 2,443 km² (943 mi²), or 9.3 percent of the total designated critical habitat in northern Maine in 2014 (79 FR 54828).

The NRCS required that lynx forest management plans must be based on the Service's "Canada Lynx Habitat Management Guidelines for Maine" (McCollough 2007, entire). These guidelines were developed from the best available science on lynx management for Maine. The guidelines required maintenance of landscapes having hare densities that support reproducing lynx populations. Notably, HFRP forest management plans provided a net conservation benefit for lynx, which was achieved by employing the lynx guidelines, identifying baseline habitat conditions, and meeting NRCS standards for forest plans. Plans met NRCS HFRP criteria and guidelines and complied with numerous environmental standards. Plans were reviewed and approved by the NRCS with assistance from the Service.

Unlike lynx forest plans on Federal lands, HFRP plans lack long term commitments beyond an initial 10-year contract period, after which longer-term commitments to lynx management are voluntary. Plans were prepared for a forest rotation (70 years) and include a decade-by-decade assessment of the location and anticipated condition of lynx habitat on the ownership. Some landowners developed plans exclusively for lynx, and others combined lynx management (umbrella species for young forest) with American marten (umbrella species for mature forest) and other biodiversity objectives. All 4 plans have been completed although contracts with NRCS expired as of 2017. Landowners have the option to convert HFRP contracts into Safe Harbor Agreements or other agreements to provide regulatory assurances, however, at this time this option has not been explored with landowners.

Many large private forest landowners in the northern Maine unit could potentially include lynx management as part of endangered species management required by forest certification programs. For example, The Nature Conservancy land enrolled in the HFRP is also enrolled in the Forest Stewardship Council (FSC) forest certification program. Other landowners are certified under the Sustainable Forestry Initiative (SFI). Both certification programs require protection of threatened and endangered species (FSC 2010, pp. 24, 27; SFI 2015, pp. 6-7). However, certification programs are also voluntary and may not include long-term commitments. Few certified landowners have consulted with the Service on forest management for lynx. In addition, “working woodland” easements now encompass > 10,000 km² (3,861 mi²) across northern Maine; although these covenants do not require specific management practices or outcomes beyond sustainable forestry, they do ensure that conversions to other land uses will never occur (MDIFW 2017, p. 2).

Lynx Status: Historically, Maine seems to have consistently had a breeding population of lynx. Early written accounts did not consistently distinguish bobcats from lynx (Hoving 2001). Prior to 1939, lynx observations were based largely on written accounts of lynx from museum records, journals, and periodicals (Vashon *et al.* 2012, p. 56). Hoving *et al.* (2003, pp. 368-369) compiled 118 lynx occurrence records (509 individual lynx) from 1833-1999, which suggest that lynx were widespread throughout the state except for the coastal areas. These records included 39 kittens representing at least 21 litters, primarily in northern and western Maine, from 1864-1999 (Hoving *et al.* 2003, p. 371). Populations apparently fluctuated, and in some years 200-300 lynx were harvested in Maine (Hoving *et al.* 2003, pp. 373-374). Lynx were later documented in winter snow track surveys conducted by MDIFW during 1994-1998 (Vashon *et al.* 2012, p. 56).

When the DPS was listed, lynx were known to be present in northern Maine but little was known about their distribution, population size and trend, snowshoe hare populations, and relationships to forest management. Since then, research from the MDIFW (Vashon *et al.* 2008a, entire; 2008b, entire; and 2012, entire) and the University of Maine (Hoving *et al.* 2003, entire; Hoving *et al.* 2004, entire; Hoving *et al.* 2005, entire; Homyack *et al.* 2005, entire; Homyack *et al.* 2007, entire; Homyack *et al.* 2006, entire; Fuller *et al.* 2007, entire; Fuller *et al.* 2004, entire; Fuller and Harrison 2005, entire; Simons-Legaard *et al.* 2013, entire; Simons-Legaard *et al.* 2016, entire) have greatly increased our knowledge. Snow track surveys and confirmed occurrence records document that lynx occur throughout northern Maine and in small, isolated pockets in western

and eastern Maine (Vashon *et al.* 2012, pp. 10, 12, 59), and small numbers of lynx have also been documented recently in northern New Hampshire (Siren 2014b, pp. 7-16), and Vermont (Bernier 2015, entire). Population size and trend are still uncertain in northern Maine, and persistence in New Hampshire and Vermont remain questionable.

This geographic unit is part of a larger, contiguous lynx population that extends into northern New Brunswick and the Gaspé region of southern Quebec. Extensive areas of contiguous forestland in this region provide high connectivity between populations in Maine and Canada. Lynx populations in adjacent southern Quebec may exhibit cyclic populations (Ray *et al.* 2002, entire), but obvious immigration of large numbers of lynx into Maine associated with hare cycles (if they occur) has not been documented (Hoving *et al.* 2003, pp. 373-374). Although potential lynx habitat in New Hampshire and Vermont is fragmented, there is near contiguous forest and connectivity for lynx movement between these areas and habitats in northern Maine (Farrell 2013, *pers. comm.*; 79 FR 54821). Areas of recent lynx breeding in New Hampshire and Vermont are not directly connected to Canadian populations, but they are connected to the larger population in northern Maine via habitat corridors in western Maine.

Lynx in the Northern Maine Unit and adjacent populations in southern Quebec and northern New Brunswick are separated from lynx populations in the interior of Canada. The St. Lawrence River restricts lynx dispersal and demographically isolates this population from those in northern Quebec, Labrador, and Ontario (Prentice *et al.* 2017, entire). However, sufficient numbers of individuals apparently cross the river on the ice each generation to prevent genetic drift of this population (Koen *et al.* 2015, entire; Prentice *et al.* 2017, entire).

When the DPS was listed, the Northern Maine Unit was not believed to contribute significantly to its persistence. However, we now believe that the extensive young, regenerating spruce-fir habitat created by large-scale clearcutting in the 1970s and 1980s may currently support the largest lynx population in the DPS (Vashon *et al.* 2012, pp. 58-59, Appendix IV; Vashon *in* Lynx SSA Team 2016a, p. 18). Habitat in northern Maine supported lynx densities in a localized area of high-quality habitat that was substantially greater than densities elsewhere in the DPS (ILBT 2013, p. 23). In 2003 when hare populations were high, lynx density (juveniles and adults) in one of Maine's highest-quality habitats was estimated to be 9.2-13.0 lynx/100 km² (Vashon *et al.* 2008a, Vashon *et al.* 2012, p. 15). At about the same time, the density of lynx in nearby Gaspé Peninsula, Quebec was estimated to be 10 lynx/100 km² (Ray *et al.* 2002). These densities are intermediate to those in Canada during the high (17-45/100 km²) and low periods (2.3-3.0/100 km²) of the lynx-hare cycle (Poole 1994, Slough and Mowat 1996, O'Donoghue *et al.* 1997). Simons (2009, p. 102) estimated that habitat on a 14,407-km² (5,563-mi²) study area (about half of the geographic unit) in northern Maine could potentially support a population of 236 to 355 adult lynx, and Vashon *et al.* (2012, pp. 58-59 and Appendix IV) estimated the potential for a population of 750 to 1,000 adult lynx in all of northern Maine in 2006. The actual number of lynx, however, is unknown because there are no methods available to count individuals over such a large geographic area.

Lynx seem to have maintained a similar distribution throughout northern Maine since the 1970s, and are found primarily north of Moosehead Lake and west of Interstate 95, with scattered pockets in western and eastern Maine (Hoving *et al.* 2003, p. 369; Vashon *et al.* 2012, pp. 10-12.) Resident lynx in small pockets of habitat outside of the core range in Maine (including New Hampshire and Vermont) may occur only ephemerally, winking on and off over time as would be expected at the periphery of the range of a metapopulation structure, and as suspected for other lynx populations at the periphery of the range (McKelvey *et al.* 2000b, pp. 25-31; Apps 2007, pp. 81, 95-104). From 1995-1998 and 2003-2008, the MDIFW conducted snow track surveys in 66 townships to document the distribution of lynx and to inform habitat modeling at the University of Maine (Vashon *et al.* 2012, p. 91). Modeled areas of potential lynx habitat were well-distributed throughout northern Maine in the early 2000s (Simons-Legaard *et al.* 2016, entire).

Lynx populations in New Hampshire and Vermont may consist of only a few animals and they may be ephemeral, although breeding has been documented in both locations in recent years. Most historical lynx records from New Hampshire are from trapping records from the 1930s to the 1960s (Brocke *et al.* 1993, pp. 71-74; McKelvey *et al.* 2000a, pp. 212-214). There were only 2 records in the 1990s. In 2003, the Service determined that, despite a lack of breeding records, a small resident population likely occurred historically in New Hampshire but no longer exists (68 FR 40087). Lynx were detected in northern New Hampshire in 2006 and have occurred there annually since then (Siren 2014b, pp. 53, 55). In 2011, 4 lynx kittens were observed in Pittsburg and were considered evidence of breeding in New Hampshire (Kilborn 2015, Appendix A, p.44). There were only 4 historical records of lynx in Vermont prior to 2003. Since then, 9 lynx sightings have been confirmed, and reproduction was confirmed in 2012 in the Nulhegan Basin when the tracks of 3 lynx, a presumed family group, were observed travelling together in late February (Vermont Fish and Wildlife 2015, Appendix A5, p. 126). Since 2012, more intensive surveys in Vermont have resulted in only a single photograph of a lynx in 2014 (Bernier 2015, pp. 1-3; Bernier 2016, *pers. comm.*). Landscape hare densities are marginal in these areas; 0.52 hares/ha (range 0.12-0.58 hares/ha) in the Nulhegan Basin of Vermont and 0.12-0.23 hares/ha in the White Mountain National Forest (Siren 2017, pp. 13, 23, 24), which may explain why lynx rarely occur.

Maine lynx had spatial and demographic parameters similar to some northern populations during the cyclic high in the snowshoe hare cycle (Brand *et al.* 1976, Parker *et al.* 1983, O'Donoghue *et al.* 1997). From 1999 to 2011, biologists with the MDIFW trapped and radio-marked 85 lynx in northern Maine and documented lynx movements and home range (Vashon *et al.* 2008a, entire; Mallet 2014, pp. 69-93), resource use (Vashon *et al.* 2008b, entire), survival (Vashon *et al.* 2012, pp. 18-21), productivity (Vashon *et al.* 2012, pp. 17-19), and other aspects of their life history (Vashon *et al.* 2012, entire). During the period when snowshoe hare populations were highest (2000-2006), Maine lynx had among the highest reproductive rates in the DPS (89 percent of adult females produced litters, average litter size was 2.74, and kitten survival was 78 percent) (Vashon *et al.* 2012, pp. 18-21). During the current (2006-present) period of lower hare density, only 30 percent of females had litters and average litter size was smaller (2.25), but kitten survival rate remained high, and was actually somewhat higher during the lower hare years (89 percent from 2006-2010, compared to 78 percent from 1999-2005;

Vashon *et al.* 2012, p. 21, table 1.5). Maine lynx have among the smallest home ranges documented in the DPS (Vashon *et al.* 2008a, p. 1482; ILBT 2013, p. 24; also see tables 3 and 4). Home range sizes were similar during periods of higher and lower hare density (Mallett 2014). Lynx populations likely increased during the period of high hare density (λ [λ] = 1.16) and declined during periods of low hare density (λ = 0.88; USFWS, Vortex 10, deterministic population simulation 2016; demographic data from Vashon *et al.* 2012, pp. 17-21).

In summary, Maine lynx and hare habitats are believed currently to be at historical highs as a result of forest regeneration following widespread clearcutting in the 1970s and 1980s and subsequent use of herbicides to suppress hardwoods in response to a spruce budworm outbreak (Hoving *et al.* 2004; Vashon *et al.* 2008b). In the Northeast prior to European settlement, lynx habitat was created and maintained by small-scale, frequent forest gap dynamic events and large-scale, infrequent (stand-replacing) forest disturbances (Seymour *et al.* 2002; Lorimer and White 2003). Historically, lynx distribution was patchy, and lynx populations likely fluctuated and may have been more dependent on immigration from Canada. At multiple scales, lynx in Maine select extensive areas of regenerating, dense (7,000 – 14,000 stems/ha) spruce-fir stands 15 to 35 years after clearcut, other even-aged harvest, or natural disturbance (Hoving *et al.* 2005; Fuller *et al.* 2007; Vashon *et al.* 2008b; Simons-Legaard *et al.* 2013). The unnaturally high amount of high-quality lynx habitat in this unit is expected to decline by 2030 because of changing forest practices, before stabilizing or increasing again by 2060 (Simons-Legaard 2016, p. 10, fig. 8; Simons-Legaard *et al.* 2016; see 5.2.1, below).

Factors Affecting Current Conditions

Regulatory Mechanisms - In response to public concern about widespread clearcutting in northern Maine (described above), in 1989 the Maine Legislature passed the Maine Forest Practices Act (MFPA). The MFPA regulates maximum size of clearcuts (about 100 ha [250 ac]), separation zones between clearcuts, harvest plans, and notification to the Maine Forest Service. Clearcuts are not banned, but require varying levels of State permits depending on their size. As a result of these regulatory requirements, clearcuts have declined substantially in annual number and acreage and have been replaced by various forms of partial harvesting (Sader *et al.* 2003, p. 349-350; McWilliams *et al.* 2005, p. 35; Legaard *et al.* 2015, pp. 14-21). Following passage of the MFPA, the percentage of acreage clearcut annually in Maine declined from 44 percent of annual harvest in 1989 to < 5 percent in 2004 (Simons 2009, pp. 45-46; Legaard *et al.* 2015, p. 18). The average size of clearcuts has been reduced from > 50 ha (125 ac; Maine Forest Service 1995, entire) to < 10 ha (25 ac; Maine Forest Service 2003, entire; 2005, entire; 2007, entire). Currently, partial harvesting comprises about 94 percent of acres cut annually in Maine (Simons 2009, p. 50). Although total timber volume harvested has changed relatively little, landowners must partial harvest about twice as many acres to harvest the same volume of wood annually that they would with clearcutting (Legaard *et al.* 2016, p. 18). Thus, the annual forest area harvested in Maine has increased from about 100,000 ha (250,000 ac) pre-MFPA to 223,000 ha (550,000 ac) post-MFPA (McWilliams *et al.* 2003, p. 35).

Currently, 28 years after implementing the MFPA, much of the 4 million-ha (10 million-ac) northern Maine landscape has been partially harvested (Legaard *et al.* 2016, p. 16) – some areas on multiple occasions. The partial harvests that replaced clearcuts include a variety of silvicultural treatments, including both even-aged (e.g., shelterwood) and uneven-aged (e.g., selection) management that result in a wide range of residual stand conditions (Robinson 2006, pp. 5-37), which have important implications for lynx conservation. Snowshoe hare densities in partially harvested forests are on average about 50 percent lower (but range from 20 to 90 percent lower) than in regenerating conifer stands created by clearcutting (Robinson 2006, pp. 5-37; Scott 2009, p. 109; Simons 2009, p. 83), thus reducing landscape hare density and, therefore, lynx habitat quality in this unit (Simons 2009, pp. 206, 209, 217; Simons-Legaard *et al.* 2016, p. 7-8; Simons-Legaard 2016, entire). Landscape level hare densities have declined with extensive partial harvesting and aging of the spruce budworm-era clearcuts, and future declines are anticipated (Simons-Legaard *et al.* 2016, 9-10; also see section 5.2.1).

Climate Change - Climate change is affecting temperature, snow, and precipitation patterns in the Northeast at rates faster than expected (Rustad *et al.* 2012, p. 6). Rapid winter warming in recent decades is believed to be influenced by an albedo effect caused by the reduced persistence of snow in winter (Hayhoe *et al.* 2006). Average winter temperatures are increasing 0.42° - 0.46°C/decade (0.76° - 0.83°F/decade) with the greatest warming occurring in the winter months, especially January and February (Burakowski *et al.* 2008). Under mid- to high-emissions scenarios, average mean temperatures in northern Maine are projected to increase by 6.7° - 7.8°C (12° - 14°F) by 2080-2099 relative to 1971-2000 (Galbraith *et al.* 2013, p. 43). Under a higher emissions scenario, snow covered days in northern Maine (from December to February) could decrease from 30 days per month observed from 1961-1990 to about 18-20 days per month in 2070-2099 (Galbraith *et al.* 2013, p. 49). Climate warming may have already affected lynx habitat in this unit by reducing the distribution of favorable snow conditions and boreal forest vegetation, and it is likely to continue to do so in the future (see section 5.2.1).

Snow Duration, Depth, and Quality - As noted in chapter 2, records of lynx occurrence are correlated with areas that regularly have at least 4 months (120 days) of continuous snow coverage (Gonzalez *et al.* 2007, p. 7). Snow cover days in northern New England (1965-2005) ranged from 60-121 days and declined an average of 3.6 days/decade from 1965-2005 (Burakowski *et al.* 2008). Snow duration declined by 16 days in the Northeast from 1970 to 2001 (Wake 2005) and is expected to diminish another 2 weeks in Maine by mid-century (Fernandez *et al.* 2015). Thus, average conditions in Maine are currently at or below the snow cover duration correlated with historical lynx occurrence records. Similarly, the largest decreases in snow depth observed in Canada in the last 6 decades have occurred in the lower St. Lawrence Valley, immediately north of Maine (Brown and Braaten 1998, pp. 48-52).

Lynx in the northeastern United States and eastern Canada occur where average annual snowfall typically exceeds 270 cm/yr (106 in/yr; Hoving *et al.* 2005), which defines the distribution of lynx (to the north) and bobcat (to the south) in this region (Hoving *et al.* 2005; Carroll 2007; Peers *et al.* 2013). Average annual snow depth at all 5 NOAA weather stations within the range of the lynx in northern Maine (1981-2010) was below this threshold and ranged

from 228-263 cm (90-104 in; NOAA 2011¹⁴). In the last 50 years, 18 of 23 snow sampling sites in and near Maine experienced reduced depth of snowpack (Hodgkins and Dudley 2006). Snow depth in New England (1965-2005) declined an average of 4.6 cm/decade (1.8 in/decade; Burakowski *et al.* 2008). Thus, average annual snowfall in Maine is currently at or below depths associated historically with lynx presence, and further declines could reduce the likelihood that resident lynx will persist in this unit (Hoving *et al.* 2005).

As noted in chapter 2, deep, unconsolidated and persistent snow is thought to provide lynx with a competitive advantage over other terrestrial hare predators and gives snowshoe hares the ability to reach winter browse. Snow quality (“fluffiness”) has deteriorated and snow density has increased in the Northeast. Unlike other units, annual precipitation in Maine is increasing because of climate change, but primarily as rain (Siren *in* Lynx SSA Team 2016a, p. 15; Fernandez *et al.* 2015), and especially rain on snow events in winter in northern Maine (Huntington *et al.* 2004; Deser *et al.* 2014; Fernandez *et al.* 2015). Snow density and compaction and crust conditions (caused by wet, heavy snow or rain on snow events in winter) have increased in northern New England (Dudley and Hodgkins 2002; Huntington *et al.* 2004; Huntington 2005; Hodgkins and Dudley 2006) and southern Canada (Karl *et al.* 1993).

Vegetation Management - The effects of forest management on foraging and denning habitat for lynx in northern Maine are discussed in the Habitat Description, Habitat Status, and Regulatory Mechanisms sections above. As described there, past vegetation management in the form of landscape-level clearcutting (sometimes followed by herbicide application to promote softwood regeneration) of budworm impacted forests is responsible for the current historically high amount of high-quality hare (and therefore lynx foraging) habitat in this unit. The amount of high-quality habitat created by these densely-regenerating stands probably peaked in the late 1990s – early 2000s and is expected to decline over the next several decades (see section 5.2.1).

Wildland Fire Management - Although fire is frequent in many boreal forest regions, it is not a stressor for lynx in northern Maine and likely played a minimal role historically in creating and maintaining lynx and hare habitats. Annual precipitation is comparatively greater in this unit than others, and conditions for large fires occur infrequently. The fire regime in this unit is one of infrequent (50- to 200-year interval) and generally small (several acres) surface fires in the dormant season. Large (up to 32,375 ha [about 80,000 ac]) stand-replacing fires are rare and occur at a less frequent interval (800 to 9,000 years; Seymour *et al.* 2002, p. 360). In contrast, spruce budworm outbreaks cause stand-replacement over large areas every 100–250 years (Cogbill, 1985).

Habitat Fragmentation - Habitat fragmentation (smaller and more isolated patches of high-quality hare habitat) caused by current forest practices in northern Maine is discussed in the Habitat Description and Habitat Status sections above.

¹⁴ <http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html>,
<https://www.currentresults.com/Weather/Maine/annual-snowfall.php>, last accessed 3.31.2016.

Other Factors: Trapping - This unit is directly connected to lynx habitats and populations in southern Quebec, where trapping of lynx is legal. In areas where lynx are trapped for furs (Canada and Alaska), trapping can be additive to other sources of mortality and have population-level effects (Brand and Keith 1979; Koehler and Aubry 1994). Thus, harvest regulations for lynx are modified (e.g., lynx quotas per trapper are reduced) when hare and lynx populations are low (Bailey *et al.* 1986). About 400 lynx are trapped and killed annually in Quebec south of the St. Lawrence River¹⁵. Several lynx that were captured and radio-marked in northern Maine were subsequently trapped in southern Quebec (Vashon *et al.* 2012).

Lynx trapping and hunting seasons were closed in Maine in 1967 (Vashon *et al.* 2012, p. 28) and also in New Hampshire and Vermont for decades prior to the DPS being listed under the ESA. In 2014, the MDIFW worked with the Service to develop an *Incidental Take Plan for Maine's Trapping Program* (MDIFW 2014, entire; 2015a as amended, entire) and obtained a permit from the Service for lynx trapped incidental to other furbearer trapping in Maine (see section 3.1.2). Trapping injury and mortality are not believed to have a population-level effect on lynx in northern Maine and adjacent Canada when lynx may be at historically high numbers, but increased, targeted lynx trapping in southern Quebec could have a synergistic and negative effect if hare and lynx populations decline, habitat declines, or climate change further stresses lynx (Slough and Mowatt 1996; Carroll 2007, pp. 1099-1103). Carroll (2007, pp. 1099-1103) modeled lynx populations in this unit and demonstrated that increased trapping pressure in Quebec could, combined with projected climate warming and associated snow loss, have a negative effect on protected lynx populations in Maine and New Brunswick.

Wind Power Development - Interest in wind energy development has increased in northern and western Maine, and such development could impact high- and low-elevation spruce-fir habitats (Whitman *et al.* 2013). Maine has experienced a rapid increase in wind energy development¹⁶, and there is increased interest in placing developments on private lands in unpopulated areas in northern Maine, New Hampshire, and Vermont. Wind energy is an increasingly appealing source of income for investment companies and other landowners who own forestland in the northern Maine unit. As of 2016, at least 11 wind projects have been proposed in northern and western Maine and 5 projects are in operation; 2 have been proposed in northern New Hampshire and 2 are in operation; and 3 have been proposed for northeast Vermont and 2 are in operation or under construction. Maine's 2 largest wind projects (combined over 250 turbines covering 932 km² [360 mi²]) are proposed entirely within Maine's designated lynx critical habitat. Although impacts of wind energy projects on lynx, hares, and their habitats have not been demonstrated, potential effects include loss and fragmentation of habitat from turbines, roads, and transmission lines, and disturbance or displacement of resident lynx. Road construction could further fragment habitat and increase access, potentially increasing vehicle collisions with lynx and other sources of mortality, including incidental trapping or illegal shooting (also see 5.2.1).

¹⁵ <http://mffp.gouv.qc.ca/english/wildlife/statistics/index.jsp>, last accessed 5.19.2016.

¹⁶ <http://www.eia.gov/electricity/data/browser>, last accessed 8.2.2016.

Changing Land Ownership and Development - Until recently, the northern Maine unit was largely undeveloped and owned primarily by about a dozen large, commercial timber interests, but land ownership patterns have changed dramatically in the last 15 years (Ippoliti and Nadeau-Drillen 2006). Large tracts of land have been sold, lumber and pulp mills shut down, and much of the area has been sold to investment-oriented owners. Some of these new landowners are seeking diversified financial returns on their investment, including developing residential housing, second homes, and resorts. At various times in the past, 2 large residential and resort areas have been proposed on forestlands within designated lynx critical habitat in this unit. Both projects, if eventually built as previously-planned, could result in the development of several thousand acres of potential lynx habitat, but would be mitigated by substantial (100,000s of acres) conservation easements on surrounding forestland. Also, a private landowner recently purchased and donated 354 km² (137 mi²) within designated lynx critical habitat that was subsequently designated as the Katahdin Woods and Waters National Monument. This area currently has a legacy of young regenerating spruce-fir habitat from previous commercial timber harvest, but its new monument designation will limit future forest management activities (timber harvest or other vegetation management) that could benefit lynx. In addition, the Nature Conservancy continues forest management on about half of its 750-km² (290-mi²) ownership in this unit, including managing part of the area for lynx.

Construction or expansion of developed areas such as residential areas and resorts and smaller recreational sites like Nordic ski huts or campgrounds may directly remove forest cover. Such habitat alteration and associated human recreation in lynx habitat could result in a more fragmented landscape and localized decreases in prey availability, and could affect lynx movements within home ranges or displace lynx from high-quality habitats. As with energy development, road and highway construction often associated with residential and recreational development can further fragment habitat and, with associated increases in traffic volumes and/or speeds and human access, can increase the likelihood of lynx mortality and injury from vehicle collisions and incidental or illegal trapping or hunting.

In summary, lynx were historically and are currently widespread throughout northern Maine, and they currently occur (and probably occurred historically) as small resident or ephemeral populations in small patches of habitat outside this geographic unit in eastern and western Maine, northern New Hampshire, and northern Vermont. According to MDIFW, habitat in northern Maine may currently support a potential population of 750 to 1,000 lynx. High-quality habitat created by extensive clearcutting 30 to 40 years ago is peaking and is projected to decline by 50 percent in the next 15 to 20 years (Simons-Legaard 2016, pp. 10-18; also see section 5.2.1). Hare densities declined by 50 percent in this unit starting in about 2006 and have remained at lower levels, and future hare fluctuations or cycles are uncertain. Recent history demonstrates that some forms of forest management have the potential to create or increase lynx habitat. However, forest practices have shifted to partial harvesting, which is less likely to create large areas of lynx habitat or maintain the current historically broad distribution of high-quality habitat generated by previous landscape-level clear-cutting. Additionally, private landowners who previously entered into commitments to manage for lynx conservation have not renewed those commitments (although the habitat will remain viable for lynx for some time).

Land ownership has also changed in northern Maine, and the majority of lands are owned now by investment companies that often wish to diversify income from their investments, which could result in forest practices inconsistent with lynx habitat conservation. Without long-term, binding land management commitments in this unit, there is no guarantee that the current historically high amount of lynx habitat will be maintained by future forest management practices on private lands. The greatest stressors to resident lynx in this unit are habitat loss (as a result of the shift in forest management from clearcutting to partial harvesting resulting in lower landscape hare densities), lack of forest planning for lynx, and projected continued climate warming (diminishing snow depth, quality and duration; transition from spruce-fir to northern hardwood forests; potential increased competition from bobcats and fishers; and increased future isolation of lynx in this unit and southeastern Canada because of diminishing ice conditions on the St. Lawrence River/Seaway).

4.2.2 Unit 2 - Northeastern Minnesota

Unit Description: This geographic unit encompasses approximately 21,100 km² (8,147 mi²) in northeastern Minnesota. It includes the area designated as critical habitat in 2014 (79 FR 54782) and an additional relatively small area of tribal land that was excluded from critical habitat. Land ownership in this unit is about 47 percent Federal (primarily USFS, with some NPS and BLM land); 36 percent State; 16 percent private; and 1 percent Tribal (Grand Portage Reservation; see table 2). This unit includes most of Superior National Forest (SNF; including the Boundary Waters Canoe Area Wilderness [BWCAW]) and Voyageurs National Park. This unit is directly connected to lynx habitats and populations in Canada, and lynx in this unit likely represent the southern extent of a larger cross-border population, most of which occurs in Ontario. Relative to other DPS lynx populations, this unit is about 1,610 km (1,000 mi) west of the Northern Maine geographic unit and about 1,480 km (920 mi) east of the Northwest Montana/Northeast Idaho Unit.

Habitat Description: In Minnesota, most lynx occurrences are associated with the Mixed Deciduous/Conifer Forest (McKelvey *et al.* 2000a, pp. 246, 248) within the Laurentian Mixed Forest Province (McNab *et al.* 2007, p. 5). Most of this province is characterized by low-relief hilly landscapes with glacial features and an elevation from sea level to 730 m (2,400 ft), including many lakes and rivers. This unit contains a mix of upland conifer and hardwood interspersed with lowland conifer, alder or willow shrub swamps and black spruce or tamarack bogs. Coniferous and mixed-coniferous/deciduous vegetation types are dominated by balsam fir; black and white spruce (*Picea glauca*); northern white cedar (*Thuja occidentalis*); Jack (*Pinus banksiana*), white, and red (*Pinus resinosa*) pine; eastern hemlock (*Tsuga canadensis*); and tamarack; mixed with aspen and paper birch (Burdett 2008, p.5; McCann and Moen 2011, p. 510). Burdett (2008, p. 57) reported that lynx in Minnesota selected regenerating forest, dominated by conifer with extensive forest edge, and that lynx beds (resting and hunting) and kill sites were associated with regenerating and mixed forest. McCann and Moen (2011, p. 513) found snowshoe hare densities were highest in regenerating forests. Female lynx selected large woody debris and dense horizontal cover in lowland conifer cover for denning in northern

Minnesota (Moen *et al.* 2008a, p. 1510), but other cover types were used if recent blowdowns were present (Moen and Burdett 2009, p. 5).

Snowshoe hare habitat in Minnesota primarily consists of conifer forests with dense low-growing understories, lowland shrub, and conifer bogs. Conifer bogs or lowland conifer forests may be especially important during declines in hare abundance by acting as refugia for hares. Early regenerating or pole-sized stands are not used as much as in other portions of their range, although older regeneration stands were used frequently in Minnesota (McCann 2006, p. 45). Sapling-sized aspen adjacent to conifer cover may also provide functional snowshoe hare habitat. In northeastern Minnesota, edge habitats and regenerating conifer stands appeared to be important for snowshoe hare populations (Burdett 2008, p. 58; McCann 2006, p. 45), as were dense habitats containing balsam fir, white spruce, and cedar (Fuller and Heisey 1986, p. 263). Recent research indicates that the red squirrel is not an important prey species for lynx in northeastern Minnesota (Burdett 2008, p. 62; Hanson and Moen 2008, p. 9).

Average annual snowfall in this unit ranges from about 180 cm (71 in) in the northwestern part of the unit near International Falls, to 219 cm (86 in) in Duluth, on the southern end of the unit, to 228 cm (90 in) in Tofte, near the lake shore on the far eastern-central part of the unit and in Isabella, near the center of the unit, to 107 cm (42 in) in Grand Portage, at the northeastern tip of the unit. More snow is produced along Lake Superior, because of the lake effect¹⁷.

Habitat Status: Friedman and Reich (2005, p. 732) conducted a spatially explicit forest composition change analysis on a 3.2 million-ha study area in northeastern Minnesota, which was based on General Land Office Survey records from the late 1800s and the 1990 USFS Inventory and Analysis Survey. The study documents altered forest tree species abundance, proportional basal area, and spatial distribution patterns. The proportionally most abundant species in northeastern Minnesota shifted from the presettlement period (spruce, 21 percent; tamarack, 15 percent; and paper birch, 15 percent) to aspen (30 percent), spruce (16 percent), and balsam fir (16 percent) in 1990. White pine declined from 20 percent to 5 percent basal area dominance, birch from 16 percent to 13 percent, spruce from 14 percent to 9 percent, and tamarack from 12 percent to 2 percent, while aspen increased from 8 percent to 35 percent basal area dominance.

The SNF continues to manage in accordance with its 2004 Forest Land and Resource Management Plan (USFS 2004a, entire). The Forest Plan emphasizes providing sustainable amounts of timber, maintaining or enhancing biodiversity, contributing to economic and social needs of the community, and managing in an environmentally sound manner to produce goods and services that provide for long-term public benefits. The Plan includes many objectives, standards, and guidelines for the protection of lynx and enhancement of lynx habitat (USFS 2004a, Appendix E) that are based on recommendations in the 2000 LCAS (Ruediger *et al.* 2000, entire). LAUs were delineated on the SNF in 2000 as the smallest landscape scale on which to analyze effects to lynx. The boundaries have remained in place since that time to allow for long term analysis of project effects. However, the SNF Plan proposed several changes of

¹⁷ <https://snowfall.weatherdb.com/d/a/Minnesota>; accessed 4/25/2016.

current LAU boundaries, such as adding LAUs to the Virginia Management Unit of the Laurentian Ranger District, and designating the BWCAW a lynx refugium.

Hare density in parts of northeastern Minnesota appears to be sufficient to support a viable lynx population (Moen *et al.* 2008a, p. 1512), with stand-level densities ranging from 0.3–2.0 hares/ha (0.12–0.8 hares/ac; McCann 2006, p. 17). Hare populations in northeastern Minnesota appear to be patchily-distributed, but are most consistently abundant in 10-30 year old regenerating forests (McCann 2006, p.45). Pellet count data prior to the 1990s show evidence of density fluctuations of snowshoe hare populations occupying Minnesota (Fuller and Heisey 1986, pp. 262-263), but these fluctuations were not observed during the 1990s (Hodges 2000a, p. 172).

This unit is directly connected to lynx habitats and populations in southern Ontario, where trapping of lynx is legal. Habitat connectivity within and between portions of northeastern Minnesota and Canada appears functional based on radio-telemetry data that have documented lynx movements in both directions between Minnesota and Ontario (Burdett *et al.* 2007, p. 458; Moen 2009, pp. 4-6; Moen *et al.* 2010b, p. 5).

Lynx Status: When the DPS was listed, it was uncertain whether a resident lynx population occurred in Minnesota. However, we now know that a reproducing resident population has persisted in Unit 2 since the DPS was listed. Moen *et al.* (2008b, p. 30) estimated a likely maximum (all available habitat occupied) number of 190-250 resident lynx in this unit, and Moen (*in Lynx SSA Team 2016a*, p. 39) recently suggested that the resident population likely fluctuates from about 50 to 200 lynx. A more precise estimate of resident population size is not available.

Average home range sizes in Minnesota were first reported as 194 km² (75 mi²) for males and 87 km² (34 mi²) for females (Mech 1980, p. 263). Later radio-telemetry data showed that males had much larger average home range sizes (267 km² [103 mi²]) than females (21 km² [8 mi²]), and that females with kittens had the smallest home ranges (Burdett *et al.* 2007, pp. 460-461). A study of radio-collared lynx in Minnesota documented approximately 40 percent of male and female lynx making long distance movements outside of their home ranges and into southern Ontario (Moen *et al.* 2010b, p. 17). Among lynx that made long-distance movements, females tended to move 100-200 km (62-124 mi) and did not return to their original home ranges in Minnesota, while males moved 50-80 km (31-49 mi) back and forth between Ontario and Minnesota (Moen *et al.* 2010b, p. 17).

The SNF and others have identified 268 unique individual lynx (48 percent female, 51 percent male) from DNA samples taken since 2000 (Catton *et al.* 2015, p. 1). This study also documented lynx hybridization with bobcat and identified 13 unique individual lynx-bobcat hybrids (5 Female, 8 Male; Catton *et al.* 2015, p. 1). The DNA analyses also showed persistence of individual lynx in Minnesota of 2 years (N = 27 lynx), 3 years (N = 11), 4 years (N = 5), 5 years (N = 6), and 1 female lynx tracked for over 5 years, who produced 7 kittens in Minnesota (Catton *et al.* 2015, pp. 3-5).

Since 2000, the Service has documented 45 lynx mortalities in Minnesota including 16 that died of unknown causes, 11 that died after being incidentally captured in traps set for other species, 9 that were hit by vehicles on roads, 7 that were illegally shot, and 2 that were hit by trains (USFWS 2016b, *unpubl. data*). In addition to the 11 trapping mortalities, another 15 lynx were documented to have been incidentally trapped but released alive. The documented incidents largely occurred during legal trapping that targeted bobcat, coyote, fox, and marten, and involved a variety of traps including foot-holds, body gripping traps, and snares. Other lynx may have been incidentally trapped but not reported. Additionally, lynx emigrating from Minnesota to Ontario are exposed to legal trapping and shooting in accordance with regulated harvest in Canada. At least a third of lynx radio-collared in Minnesota spent time in Ontario; 4 radio-collared lynx were legally harvested (trapped) in Canada between 2003 and 2010, and 2 died in Ontario of unknown causes (USFWS 2016b, *unpubl. data*). Some of these mortalities occurred years after the lynx was last located in Minnesota, indicating, along with evidence of lynx returning to Minnesota after dispersing to Ontario, that survival of Minnesota lynx in Ontario for extended periods is possible (Moen 2009, pp. 2-3, 10-13). Minnesota has relatively high forest road and highway densities that intersect lynx habitat and several radio-collared lynx in Minnesota inhabited home ranges that were bisected by highways.

Factors Affecting Current Conditions

Identified factors potentially affecting current conditions for lynx in Minnesota include reduction in habitat quality or quantity, habitat fragmentation, climate change, increased access for competing hare predators, and human-caused mortality. The SNF is currently implementing the 2004 SNF Plan (USFS 2004a, entire), which has direction based on the LCAS (Ruediger et al. 2000, entire) and the Canada Lynx Conservation Agreement (CA) between the Forest Service and the Service (USFS and USFWS 2000, entire), for all forest activities that occur within LAUs. Active management of forest lands can create, maintain, and restore lynx habitat, and the SNF has a long-term commitment for doing so; however, private landowners do not. Under the Sustainable Forest Resource Act of 1995, the Minnesota Forest Resources Council (MNFRC) has developed guidelines for site-level timber harvesting and forest management (MNFRC 2012, p. 1); these voluntary guidelines are intended for private and State landowners and include some general recommendations for wildlife including lynx. The implementation of the MNFRC guidelines is monitored annually (e.g., MNDNR 2016b, p. 2). Thus, the several risk factors are being minimized and managed to promote the conservation of lynx within the SNF, however implementation of the guidelines on privately owned lands is voluntary.

Activities that change forest structure can affect habitat quantity and quality for lynx and snowshoe hares, their primary prey source. Thinning and other timber management practices that reduce stem density and downed material and promote more open, mature stands can reduce habitat quality and quantity. Throughout the SNF and northern Minnesota, human activities have reduced connectivity between patches of suitable lynx habitat. Development for residential and commercial uses, as well as roads, railroads, and utility corridors have all interrupted linkage corridors. Mineral exploration and development is increasing in portions of

Minnesota, particularly for hard rock (non-ferrous) minerals. Some of the area of interest for minerals overlaps with lynx habitat in northeastern Minnesota. Mineral exploration may result in short-term displacement of lynx. Mining activities and associated development may result in an irreversible loss of habitat or increased mortality risk. The specific effects to lynx and their habitat will depend on the scale and type of each project.

Roads are a factor in human-caused lynx mortality where they provide access to areas where lynx occur, increasing the risk of negative interactions between people and lynx. Throughout the SNF outside the BWCAW, high and low standard roads bisect many areas that provide potential or suitable lynx habitat. Additionally, bobcat harvest in northeastern Minnesota has been increasing over the last decade (Erb 2012, unpaginated), although it is still very rare in the area occupied by resident lynx in this unit. Where lynx and bobcat overlap, there is potential for accidental shooting and increased incidental trapping of lynx.

Winter road use, snowmobiling, cross country skiing, and dog sledding all increase the amount and distribution of compacted snow conditions, which may increase access by potential lynx competitors or predators to snowy areas from which they may otherwise be excluded (ILBT 2013, pp. 80-82). However, results of research on whether these activities result in increased competition or predation are ambiguous (ILBT 2013, p. 81) and impacts, therefore, are uncertain. Outside the BWCAW, snowmobile activity is extensive and increasing significantly. The SNF has 1,135 km (705 mi) of snowmobile trails and 2,514 km (1,562 mi) occur on all ownerships within the National Forest boundary (USFS 2011a, p. 38). Advances in snowmobile capabilities have raised concerns about intrusion and snow compaction in areas previously not vulnerable to high levels of snowmobile use. In addition, new road construction in lynx habitat has made more areas accessible during winter. These routes could be used by snowmobiles even if new roads are designated as closed to motorized public travel during other seasons. The SNF has 3,101 km (1,927 mi) of low standard roads and 254 km (158 mi) of temporary roads (USFS 2011a, p. 38). Increases in these activities have the potential to reduce the competitive advantage lynx are believed to have in areas that typically receive deep, persistent, unconsolidated snows.

As described in Chapter 2, lynx are adapted for surviving in areas that have cold winters with deep, fluffy snow, where they are thought to outcompete potential competitors such as bobcats, coyotes, and wolves. The geographical distribution of bobcat harvest in Minnesota has remained relatively static with a lack of harvest in the Arrowhead Region of Minnesota (the region encompassed by Cook, Lake, and St. Louis counties in northeastern Minnesota; Erb 2009 cited in Kapfer 2012, p. 16; Erb 2012, unpaginated) and annual snow track and scent stations surveys support the conclusion that bobcats are as rare in the Arrowhead Region as harvest indicates (MNDNR, *unpubl. data*, cited in Kapfer 2012, p. 23). However, this may change with decreased snow conditions predicted to result from continued climate warming (Kapfer 2012, p. 25; see section 5.2.2). Bobcat and coyote populations already appear to be increasing in Minnesota (Erb 2014, p. 40). If snow depth and duration decrease in the Arrowhead Region as projected by climate models, deer mortality may be reduced; this could increase bobcat densities and facilitate bobcat expansion into northeastern Minnesota (Kapfer

2012, p. 25), potentially increasing bobcat-lynx hybridization (Koen *et al.* 2014b, p. 113). According to annual track surveys, wolf populations in Minnesota are currently stable (Erb 2014, p. 40); however, similar to bobcat, wolf populations may increase with changing snow conditions and prey availability as influenced by climate change.

In summary, although lynx residency in the unit was uncertain when the DPS was listed, we now understand that it supports a persistent resident population that is thought to fluctuate from 50-200 individuals, likely in response to hare population changes that affect lynx survival, productivity, and recruitment. We have no evidence to suggest that this area historically supported a larger population or a broader distribution of habitat capable of supporting persistent lynx occupancy. Although recent research has improved our understanding of lynx distribution, habitat requirements, dispersal, and some demographic parameters in this unit, we still lack information on kitten survival, recruitment, and the influence of immigration and emigration on population persistence.

4.2.3 Unit 3 - Northwestern Montana/Northeastern Idaho

Unit Description: This geographic unit includes the parts of northwestern Montana and northeastern Idaho the Service designated as critical habitat for lynx in 2014 and some Tribal and State lands that were excluded from that designation (79 FR 54825). It encompasses approximately 27,000 km² (10,424 mi²) in portions of Boundary County in Idaho and Flathead, Glacier, Granite, Lake, Lewis and Clark, Lincoln, Missoula, Pondera, Powell and Teton Counties in Montana. Ownership in this unit is 84 percent Federal (USFS, NPS, and BLM); 8 percent private; 4 percent State; and 4 percent Tribal. Most Federal lands in this unit (82 percent) are on national forests managed by the USFS; with NPS (16 percent) and BLM (almost 2 percent) contributing most of the remainder. This unit includes most of Glacier National Park and parts of the Flathead, Helena, Idaho Panhandle, Kootenai, Lewis and Clark, and Lolo National Forests, the BLM's Garnet Resource Area, and the Confederated Salish and Kootenai Tribes Flathead Reservation. It also includes (from northwest to southeast) all or parts of the Purcell, Cabinet, Salish, Whitefish, Lewis, Flathead, Swan, and Garnet mountain ranges. Several areas adjacent to this unit are known or thought to support a small number of resident lynx, at least intermittently, including the southern Selkirk Mountains of northern Idaho and northeastern Washington and the western Cabinet Mountains of northern Idaho (USFS 2015a, pp. 9-10; Lucid 2016, pp. 7-11; Lucid *et al.* 2016, pp. 158-160; IDFG 2017, pp. 2-5), and a small area of the Helena National Forest just south of MacDonald Pass, between Helena and Missoula (Gehman *et al.* 2011, p. 21). This unit is directly connected to lynx habitats and populations in Canada, and lynx in this unit may represent the southern extent of a larger cross-border population that also occurs in southwestern Alberta and southeastern British Columbia. Relative to other DPS lynx populations, this unit is about 200 km (125 mi) east of the north-central Washington unit, about 145 km (90 mi) northwest of the GYA, and about 1,480 km (920 mi) west of the Northeastern Minnesota geographic unit.

Habitat Description: In the Northern Rocky Mountains, most lynx occurrences are associated with the Rocky Mountain Conifer Forest or Western Spruce-Fir Forest vegetative classes

(Kuchler 1964, p. 4; McKelvey *et al.* 2000a, p. 246) at elevations ranging from 1,250 m (4,100 ft) to 2,500 m (8,200 ft; Aubry *et al.* 2000, pp. 378–380; McKelvey *et al.* 2000a, pp. 243–245). The dominant vegetation that constitutes lynx habitat in these areas is subalpine fir, Engelmann spruce and lodgepole pine (Aubry *et al.* 2000, p. 379; Ruediger *et al.* 2000, pp. 4-8 - 4-10). Within these vegetation types, lynx appear to prefer areas of moderate to gentle topographic relief (Koehler and Aubry 1994, p. 86; Apps 2000, p. 352; Squires *et al.* 2013, pp. 187, 191). Lynx use large landscapes that include a temporally- and spatially-shifting mosaic of forest age classes, where natural or anthropogenic disturbances may reset forest succession (ILBT 2013, p. 28). Early successional stages that often provide dense horizontal cover at ground/snow level and support high hare densities (Griffin 2004, pp. 53-54, 70; Squires *et al.* 2010, pp. 1654-1656) may be created and maintained by natural disturbance processes including wildfire, insect infestations, tree diseases, and wind events (ILBT 2013, p. 28). Timber harvest, other silvicultural treatments, wildfire management, or other vegetation management, which may be beneficial, benign, or adverse to lynx and hare habitats depending on prescription, extent, and implementation, can also influence the amount and distribution of early successional stands (Agee 2000, p. 39; ILBT 2013, pp. 28, 71-76). Likewise, natural disturbance regimes and forest management can also influence the amount and distribution of mature multi-story spruce-fir stands, which can include dense horizontal structure, support high hare densities (Griffin 2004, pp. 53-54, 70; Squires and Ruggiero 2007, pp. 313-314; Berg *et al.* 2012, pp. 1483-1485), and provide preferred winter foraging habitat for lynx (Squires *et al.* 2010, pp. 1653-1657).

In northwestern Montana, lynx generally occur in mid-elevation (1,260 – 2,355 m [4,130 – 7,730 ft]) moist subalpine mixed-conifer forests dominated by Engelmann spruce and subalpine fir and including Douglas-fir, western larch (*Larix occidentalis*), and lodgepole pine (Squires *et al.* 2010, pp. 1653-1654). Lynx home ranges occur in areas with low surface roughness (i.e., low topographic relief; gently-sloping to moderately-steep terrain), high canopy cover indices, and little open grassland (Squires *et al.* 2013, p. 191). These lynx habitats occur below the alpine zone and above drier, more open forest types (e.g., ponderosa pine and dry Douglas-fir/western larch/lodgepole pine) that do not provide lynx habitat (Agee 2000, p. 42; Berg 2009, p. 20; Squires *et al.* 2010, p. 1655). As elsewhere in the western portion of the DPS, this elevational pattern contributes, along with the transition from boreal to more temperate forests, to a naturally patchier, more fragmented distribution of lynx habitat than in the continuous boreal forest landscape in the core of the lynx's North American range in northern Canada and interior Alaska (65 FR 16052-53; 68 FR 40089; Squires *et al.* 2006[a], pp. 46-47; ILBT 2013, pp. 76-77; Squires *et al.* 2013, p. 191; 78 FR 59438). Squires *et al.* (2013, pp. 187-189) used telemetry data to model the distribution of probable lynx habitat in a 36,096-km² (13,937-mi²) study area that completely overlaps this geographic unit. Their results indicate that much of the area has a low to moderate probability of selection by lynx, and that the areas with higher selection probabilities are relatively small and patchily- but widely-distributed throughout the unit and are separated by intervening areas of low probability of lynx use (Squires *et al.* 2013; see fig. 1(a), p. 189). Holbrook *et al.* (2017, entire) recently corroborated this result. This patchy distribution of high-quality habitats interspersed with areas of low-quality or non-habitat results in naturally lower densities of both snowshoe hares and lynx than those typical (except during hare cycle lows) in the continuous boreal forests of northern Canada and Alaska (Wolff 1980, pp. 123–128;

Buehler and Keith 1982, pp. 24, 28; Koehler 1990a, p. 849; Koehler and Aubry 1994, p. 84; Aubry *et al.* 2000, pp. 373–375, 382, 394).

In this unit, female and male lynx exhibit strong selection for advanced (25- to 40-year-old) regenerating spruce-fir stands in both winter and summer and at all levels of proportional availability (ranging from about 5 to 40 percent) of this stand type on the landscape (Holbrook *et al.* 2017, pp. 10-18 and fig. 6). In winter, females and males both preferentially use mature multi-story spruce-fir stands with dense horizontal cover, particularly when it is less available, proportionally, on the landscape, and they avoid clearcuts and large forest openings (Squires *et al.* 2010, pp. 1648, 1653–1656; Holbrook *et al.* 2017, pp. 10-18 and fig. 6). In summer, lynx also select young stands with dense spruce-fir saplings, avoid mature forest, do not appear to avoid openings as in winter, and use slightly higher elevations (Squires *et al.* 2010, pp. 1648, 1653–1656; Holbrook *et al.* 2017, pp. 13, 18). Both mature multi-story and young regenerating stands provide dense horizontal structure at ground/snow level, which supports higher snowshoe hare densities than more open young or mature forests. In the central (Seeley Lake study area) part of this unit, during an apparent regional hare decline in 1999-2001, summer hare densities were highest (up to 1.4 hares/ha [0.6 hares/ac] in 1 study area) in dense young stands, and winter densities were highest (up to 1.8 hares/ha [0.7 hares/ac] in 1 study area) in dense mature stands (Griffin and Mills 2009, pp. 1492-1496). Over a longer interval (1999-2003) when hare populations in this area were thought to be stable, mean summer and winter hare densities, respectively, were 0.34 and 0.53 hares/ha (0.14 and 0.21 hares/ac) in dense mature stands and 0.64 and 0.47 hares/ha (0.26 and 0.19 hares/ac) in dense young stands – habitats selected by lynx, compared to 0.18 and 0.20 hares/ha (0.07 and 0.08 hares/ac) in open mature stands and 0.18 and 0.12 hares/ha (0.07 and 0.05 hares/ac) in open young stands that lynx did not select (Squires and Ruggiero 2007, pp. 313-314). Even the relatively higher hare densities in the dense young and dense mature stands only marginally achieve the threshold density of 0.5 hares/ha (0.2 hares/ac) thought necessary to support lynx within home ranges (Ruggiero *et al.* 2000b, pp. 446–447; ILBT 2013, pp. 24, 26, 90; also see section 2.2.1). Nonetheless, hares accounted for 96 percent of the biomass in lynx diets in this unit based on evidence at kill sites (Squires and Ruggiero 2007, pp. 310-313), suggesting that even small declines in landscape-level hare densities could reduce the ability of habitats in this unit to support resident lynx (Squires *et al.* 2010, p. 1656).

Lynx in this unit generally den in mature spruce-fir forests among downed logs or root wads of wind-thrown trees in areas with abundant coarse woody debris and dense understories with high horizontal cover in the immediate areas around dens (Squires *et al.* 2004a, table 3; Squires *et al.* 2008, pp. 1497, 1501–1505). Dens are located farther from forest edges than random expectation are few occur in young regenerating or thinned stands with discontinuous canopies (Squires *et al.* 2008, p. 1497).

Average annual snowfall in this unit ranges from about 142 cm (56 in) in the Kalispell/Whitefish/West Glacier area of northwestern Montana to 183 cm (72 in) in Nordman in northern Idaho, to 216 cm (85 in) in Lincoln, Montana, near the southern end of the unit, to 259 cm (102 in) in Rexford, Montana near the Canada-United States border, to 345 cm (136 in) in Seeley Lake,

Montana, in the central part of the unit, with most snow falling from November to March in each place¹⁸.

Habitat Status: Most lynx habitat in this unit is currently designated as critical habitat in accordance with the ESA. Over 84 percent (22,761 km² [8,788 mi²]) of this unit is in Federal ownership, including 18,695 km² (7,218 mi²) in national forests under USFS management, 3,658 km² (1,412 mi²) in Glacier National Park managed by NPS, and 397 km² (153 mi²) managed by BLM in its Garnet Resource Area. As described above, potential lynx habitat in this unit is patchily-distributed and interspersed with areas of non-habitat (matrix). Among the 6 national forests that contribute lands to this geographic unit, potential lynx habitat was mapped on about 54 percent of the total national forest area (both inside and outside this SSA unit; USFWS 2007, pp. 32, 95, 122-123). In Glacier National Park, 2,976 km² (1,149 mi²; about 73 percent of the park) is considered “lynx forest types” (65 FR 16073), but only 1,103 km² (426 mi²; 27 percent of the park, 37 percent of lynx forest types) is estimated to be lynx habitat (68 FR 40086, 40089). In the Garnet Resource Area, the BLM designated 5 LAUs (which approximate a lynx home range) covering 947 km² (366 mi²), of which, 574 km² (222 mi²; about 61 percent) was mapped as lynx habitat (Sparks 2016a, *pers. comm.*).

Federal lands are managed as either “developmental” or “nondevelopmental” land use allocations (68 FR 40093). Lands in developmental allocations are managed for multiple uses, such as recreation and timber harvest, some of which may conflict with lynx conservation. Management within non-developmental allocations focuses on the maintenance of natural ecological processes, or conservation of rare ecological settings or components, and these areas include wilderness, roadless, and semi-primitive non-motorized areas (USFWS 2007, pp. 33, 77). Timber harvest, road construction, and fire suppression typically do not occur or are very limited in lands managed in non-developmental allocations.

In this SSA unit, almost 46 percent of the Federal land and 40 percent of the entire unit is in designated wilderness or National Park land. This includes (in addition to Glacier National Park) the 6,297-km² (2,431-mi²) Bob Marshall Wilderness Complex (Bob Marshall, Great Bear, and Scapegoat wilderness areas) on the Flathead, Lewis and Clark, Helena and Lolo National Forests; the 302-km² (117-mi²) Mission Mountain Wilderness on the Flathead National Forest; the 139-km² (54-mi²) Rattlesnake Wilderness Area on the Lolo National Forest; and the 371-km² (143-mi²) Mission Mountain Tribal Wilderness on the Flathead Reservation. Management of NPS lands and both national forest and Tribal wilderness areas provides land-use restrictions that are likely beneficial to lynx (65 FR 16073; USFWS 2014, pp. 28-29; 79 FR 54831), and adverse effects of management activities on lynx habitats in these areas are unlikely. Among the 6 national forests that contribute to this unit, 56 percent of potential lynx habitat is in designated wilderness or roadless areas (USFWS 2007, p. 34).

Much of the remaining USFS lands and the BLM lands have developmental land-use allocations where some management activities have the potential to impact lynx or its habitat. However, as described above in section 3.1.1, USFS lands in this unit are managed in accordance with the

¹⁸ <https://snowfall.weatherdb.com/d/a/Montana>; accessed 4.2.2016.

NRLMD, which formally amended all forest plans to adopt and implement lynx conservation measures (USFS 2007, pp. 8-30 and Attachment 1, pp. 1-9) that were developed based on the scientific findings and recommendations of the LCAS (Ruediger *et al.* 2000, pp. pp. 7-1 - 7-18). Similarly, the BLM in 2004 amended the Resource Management Plan (RMP) for the Garnet Resource Area to incorporate the conservation measures identified in the LCAS (BLM 2004a, 2004b, entire; Sparks 2016b, *pers. comm.*). Both documents provide guidance on the kinds of activities that can and cannot be implemented in important lynx habitats and thresholds for the proportions of lynx habitat in LAUs that can be in an unsuitable state at any given time and how much can be converted from suitable to (temporarily) unsuitable over particular time frames. Implementation of these plans has likely benefitted lynx by providing a consistently applied framework for conserving and restoring important hare and lynx habitats.

Habitat status on private lands, which account for about 8 percent of lands in this unit (2,172 km² [839 mi²]), is governed by some Federal and State regulations and by a number of private-public conservation partnerships and State agency efforts. As described in section 3.1, some Federal and State regulations guide some activities on private lands, including the ESA's prohibition on take of listed species, and State regulations governing trapping and timber management. In addition to these protections, there have been several other notable lynx conservation achievements on private lands in this unit since the DPS was listed. Two of these, the Clearwater-Blackfoot Project and the Montana Legacy Project, are multi-partner and community efforts led by The Nature Conservancy in Montana to purchase large tracts of private commercial timberlands, conveying some to the State of Montana and the USFS for conservation management, and acquiring conservation easements on others (TNC 2016a, 2016b, 2016c, entire). These land acquisitions have resulted in protection of roughly 673 km² (260 mi²) of important lynx habitat within this SSA unit and another 583 km² (225 mi²) just to the south and west that may occasionally or temporarily support lynx or provide dispersal habitat. Additionally, the MTFWP has acquired fee title or conservation agreements on 3,096 km² (1,195 mi²) of private lands in western Montana, including 162 km² (63 mi²) in designated lynx critical habitat in this SSA unit, with ongoing efforts on another 106 km² (41 mi²) in the northwest part of the unit (MTFWP 2016, pp. 1, 3).

In addition to the MTFWP's efforts to acquire private lands and protect them through fee title or conservation agreement, the State of Montana has also worked to protect lynx habitat on State-owned lands, which account for about 4 percent of the lands in this unit (1,106 km² [427 mi²]). As described above in section 3.1.2, the MTDNRC worked closely with the Service to develop the *State of Montana Department of Natural Resources and Conservation Forested State Trust Lands Habitat Conservation Plan* (MTDNRC HCP; MTDNRC and USFWS 2010a, 2010b, 2010c, entire); a multi-species HCP that focuses primarily on commercial forest management. The HCP includes a Lynx Conservation Strategy that minimizes impacts of forest management activities on lynx, describes conservation commitments that are based on recent information from lynx research in Montana, and commits to active lynx monitoring and adaptive management programs. The HCP covers about 2,220 km² (857 mi²) of forested State trust lands in western Montana, including 703 km² (271 mi²) within this SSA geographic unit (about 64 percent of State lands in this unit). The goal of the HCP's Lynx Conservation Strategy is to

support Federal lynx conservation efforts by managing for habitat elements important to lynx and their prey that contribute to the landscape-scale occurrence of lynx. Specific objectives to achieve this goal include protecting den sites and potential denning habitat, mapping and maintaining lynx foraging habitats and limiting the spatial and temporal scope of their conversion to unsuitable conditions from forest management activities, and providing for habitat connectivity (MTDNRC and USFWS 2010b, pp. 2-45 - 2-61). The HCP was finalized and permitted by the Service in 2011, and includes a 50-year commitment by the State to manage for lynx conservation on these lands (79 FR 54835-37).

Tribal lands of the Flathead Reservation account for almost 4 percent of this unit. In addition to the Tribe's approach to lynx management described in section 3.1.2, most lynx and lynx habitat on the reservation occur in areas with formal protective status, including: (1) The long-designated Mission Mountains and Rattlesnake Tribal Wilderness Areas, which are largely roadless and managed for wilderness qualities; (2) the South Fork/Jocko Primitive Area, which is open to use only by Tribe members and in which commercial timber harvest is prohibited; and (3) the Nine-mile Divide country, which is marginal in terms of lynx habitat, but which is also partly roadless (Courville 2014, *pers. comm.*; 79 FR 54831).

As elsewhere in the DPS, winter foraging habitat is thought to be the most limiting habitat for lynx in this unit (Squires *et al.* 2010, p. 1656; ILBT 2013, pp. 20, 27). As described above, lynx selected mature multi-story stands with dense horizontal structure and relatively higher winter hare densities (Squires *et al.* 2010, pp. 1648, 1653–1656). Because of this preference, the Forest Service in the NRLMD adopted a vegetation management standard (VEG S6) that precludes all vegetation management activities that could reduce winter snowshoe hare habitat in multi-story forests, not just precommercial thinning as recommended in the LCAS (USFS 2007, pp. 13-14). Also as elsewhere (Moen *et al.* 2008a, p. 1512; Organ *et al.* 2008, pp. 1514, 1516–1517, ILBT 2013, p. 30; 79 FR 54790), denning habitat is not thought to be a limiting factor for lynx in this unit (Squires *et al.* 2008, p. 1505). Nonetheless, the NRLMD includes guidance to ensure adequate denning habitat remains well distributed in LAUs and, therefore, across the larger landscape and to design projects to create or retain coarse woody debris in areas where denning habitat may be lacking (USFS 2007, p. 17). Snow conditions in this unit also appear to remain suitable to allow lynx to outcompete other terrestrial hare predators. Gonzalez *et al.* (2007, pp. 4-7) compared the highest-precision lynx occurrence data in the contiguous United States from 1966-1998 with snow-cover data available for those locations and concluded that lynx require nearly continuous snow cover from December through March. The authors modeled snow suitability across North America, showing that this geographic unit currently has a 90-95 percent probability of providing snow cover consistent with historical lynx occurrence records (Gonzalez *et al.* 2007, p. 12).

Overall, although naturally fragmented and patchily-distributed, lynx habitat in this geographic unit appears to be largely intact relative to historical conditions and disturbance regimes, with only a small proportion apparently impacted by past management (timber harvest and precommercial thinning) activities (65 FR 16072). Despite some likely localized impacts of past timber management and infrastructure (e.g., highway) development and evidence of minor

genetic differentiation among lynx subpopulations (see *Lynx Status*, below), past management activities do not appear to have diminished this unit's ability to support resident lynx or to have created barriers to lynx movement, or to have had other landscape- or population-level effects.

A possible exception may be in the Garnet Mountains, which are known to have supported a small number of resident lynx in the 1980s and recently from 2002-2010, but where more recent surveys and research trapping efforts failed to detect lynx from 2011 to 2015 before a single lynx was verified in 2016 (Squires *in* Lynx SSA Team 2016a, p. 20; Lieberg 2017, *pers. comm.*; also see *Lynx Status*, below). This small and relatively isolated island of lynx habitat (Squires 2014, p. 4) at the southern end of this unit is thought to be capable of supporting 7-10 lynx home ranges (Squires 2016, *pers. comm.*). The BLM (2004, pp. 4-5) contrasted current and historical distributions of lynx habitats in the Garnets and found that early-successional stands (future hare and lynx foraging habitats) were at 25-50 percent of the historical condition in lower-elevation (1,370-1,830 m [4,500-6,000 ft]) lynx habitats, and 10-30 percent in higher-elevation (1,675-2,130 m [5,500-7,000 ft]) habitats. Late-successional (mature multi-story) stands (25-75 percent of historical condition) and large (> 100 ha [250 ac]) patches (25-50 percent of historical condition) were also underrepresented at lower elevations, but at higher elevations, these 2 stand types exceeded 200 percent and 100 percent of historical conditions, respectively. Lower elevation habitats were fragmented by roads and past management practices (i.e., timber harvest), while higher-elevation habitat patterns were attributed to the absence of disturbance, including fire (BLM 2004, p. 5), though fire absence was not attributed to suppression.

As discussed for the GYA in section 2.3.2.2, whether the recent absence of resident lynx in the Garnets represents the extirpation of a previously-persistent small population (and, therefore, a contraction in the range of resident lynx in this unit) or a temporary "winking off" of a naturally ephemeral small peripheral population, as might be expected in a mainland-island metapopulation structure, is uncertain and perhaps irresolvable. If residency was intermittent or ephemeral historically, the current absence of resident lynx might be a natural condition related to the area's naturally fragmented habitats and generally low hare densities - i.e., it may naturally be capable of supporting resident lynx only intermittently when habitat conditions and hare densities are optimal. If so, future intermittent lynx occupancy would be expected, but only if lynx dispersing from a source population immigrate to the Garnets when habitat conditions and hare densities return to more favorable levels. Conversely, if the Garnets historically supported a small but persistent population that was recently extirpated, it may suggest that the alteration of the historical distribution of some habitats in some parts of the range, described above, was enough to shift the quality of the area's habitat from capable of supporting a small resident population to no longer capable of doing so.

In summary, almost all lands in this unit are managed to conserve lynx and hare habitats in accordance with Federal, State, and Tribal regulations and management direction, conservation easements, and an approved HCP. Much of the area consists of designated Federal and Tribal wilderness areas and other nondevelopmental land use allocations, where management activities with the potential to adversely affect lynx generally do not occur. On lands with development allocations, USFS, BLM, and State management are based on plans that

incorporate the conservation guidance identified in the LCAS as informed by more recently available scientific information. The State and TNC, working with other conservation partners, have bought or acquired conservation easements on large tracts of high-quality private lands in the unit that are known or suspected to be occupied by resident lynx. These efforts and management across multiple ownerships likely preclude landscape-level management-related adverse impacts to the vast majority of existing lynx and hare habitats in this unit. Nonetheless, past management activities that occurred prior to implementation of current regulations and other conservation efforts may exert continuing influence on current habitat quality in some places, as described above for the Garnet Mountains. Because lynx habitats in this unit, like most other areas of the DPS range, are naturally highly-fragmented, and most have hare densities that barely meet the 0.5 hares/ha (0.2 hares/ac) threshold thought necessary to support resident lynx, relatively minor impacts, especially to hare and lynx foraging habitats, may strongly influence lynx persistence in some parts of this unit.

Lynx Status: There are no reliable estimates of the historical or current number of resident lynx in this unit although, as described in section 2.3.2.2 above, it is thought to be capable of supporting perhaps 200-300 lynx (Squires *in* Lynx SSA Team 2016a, p. 41). This is substantially fewer than previous estimates of more than 1,000 lynx, which were based on a habitat area/density index and broad assumptions regarding habitat suitability and lynx distribution (65 FR 16058) that are not supported by current understanding of lynx habitat requirements and current or historic habitat availability in this unit. That is, based on our understanding of lynx habitat and its current and historical distribution, it is very unlikely that this unit and surrounding areas were ever (recently or historically) capable of supporting 1,000 resident lynx. As described above, habitats capable of supporting resident lynx in this unit are (and also were historically) naturally patchier and less-broadly distributed (Squires *et al.* 2006a, pp. 46-47; Squires *et al.* 2013, p. 191), and lynx therefore naturally rarer, than was thought at the time of listing (ILBT 2013, p. 23; Jackson *in* Lynx SSA Team 2016a, p. 12). Although the exact distribution of resident lynx remains uncertain, this unit has a long and continuous history of lynx occurrence and evidence of reproduction (McKelvey *et al.* 2000a, pp. 224-225; Squires and Laurion 2000, pp. 346-348; Squires *et al.* 2008, entire; Squires *et al.* 2013, entire; ILBT 2013, p. 57; 65 FR 16058; 68 FR 40090; 74 FR 8643; 79 FR 54825). Genetic analyses revealed minor fine-scale genetic sub-structuring among lynx subpopulations in the southern (Garnet Mountains), central (Seeley Lake), and northern (Purcell Mountains) parts of this unit, suggesting limited interaction among lynx in those areas (Schwartz *in* Lynx SSA Team 2016a, p. 12 and Appendix 5; Squires *in* Lynx SSA Team 2016a, p. 20). Lynx in this unit likely represent the southern periphery of a larger population in southwestern Alberta and southeastern British Columbia, but the extent to which lynx persistence in this area may rely on immigration from Canada is unknown, and there is no indication of substantial immigration (irruptions) of lynx from Canada into this unit after the 1980s (Squires *in* Lynx SSA Team 2016a, p. 20).

From 1998 to 2007, researchers with the Forest Service's Rocky Mountain Research Station (RMRS) in Missoula trapped and radio-marked 175 lynx in northwestern Montana and collected nearly 170,000 GPS and over 3,000 VHS telemetry locations documenting lynx movements, resource use, survival, and productivity (Squires *in* Lynx SSA Team 2016a, p. 20). From 1999-

2007, litter sizes averaged 2.24 kittens/litter (N = 33) in the Seeley Lake area and from 2003-2007, 2.95 kittens/litter (N = 22) in the Purcell Mountains. In Seeley Lake, 61 percent of breeding-age females (N = 52) produced kittens; in the Purcells, 83 percent of females (N = 28) produced kittens. Recent research (Kosterman 2014, entire) suggests that the probability that a female produces a litter and initial litter size are correlated positively with mature forest connectivity and negatively with fragmentation in female home ranges (Squires *in* Lynx SSA Team 2016a, p. 20 and Appendix A). Annual survival rates for subadult and adult female lynx were 0.52 and 0.75, respectively, in Seeley Lake, and 0.68 and 0.85, respectively, in the Purcells. Kitten survival rate was 0.58 in Seeley Lake (Kosterman 2014, pp. 13, 30). There was no evidence of cyclicity in these vital rates, and no indication of substantial immigration of lynx into these study areas from Canada. Starvation, predation by cougars, and human-caused deaths each accounted for roughly one-third of documented sources of lynx mortality. Population viability analyses yielded population growth rates (λ) of 0.92 for the Seeley Lake area (i.e., declining population trend, 1999-2007) and 1.16 for the Purcells (increasing trend, 2003-2007). However, as described in section 2.2.2, estimates of λ in a cyclic Canadian population of lynx ranged from 2.03 (annual doubling) when hares were abundant to 0.10 (order of magnitude decline) after hare populations crashed (Slough and Mowat 1996, p. 952, table 4), and the natural range in λ that would be expected among peripheral, isolated, or semi-isolated and non-cyclic or weakly-cyclic lynx populations in the DPS versus those that would signal long-term population decline or instability is unknown. Also as noted above, estimates of λ in this unit assumed no immigration, which is a questionable assumption, and only low numbers of immigrants (less than 1 female/yr on average for a hypothetical population of 100 lynx) would be needed to provide population stability or even growth (Schwartz 2017, p. 4).

As described above, lynx distribution in this unit may have contracted with the recent apparent disappearance of resident lynx from the Garnet Mountains in the southern part of the unit. This area is thought to have habitat capable of supporting 7-10 lynx home ranges (Squires 2016, *pers. comm.*). As described in section 2.3.2.2 and above, whether the recent absence of lynx from this part of the unit represents the extirpation of a small but previously persistent population (and, therefore, a permanent contraction of lynx distribution in this unit) or the temporary “winking off” of a peripheral subpopulation that may become “winked on” again in the future is unknown. On February 2, 2016, a single lynx was detected via snow-track survey and verified via DNA analysis in the Garnet Range in the area previously occupied by resident lynx, demonstrating that natural recolonization of this area by dispersing lynx is possible. However, this recent record appears to have been of a dispersing/transient individual because subsequent surveys have not revealed additional detections of that lynx or any other lynx in the area, and there currently remains no evidence of lynx residency in this mountain range (Lieberg 2017, *pers. comm.*).

Snow-tracking, hair-snare, and camera-trap surveys in other parts of this unit since the DPS was listed continued to detect lynx on the Flathead, Helena, Idaho Panhandle, Kootenai, Lewis and Clark, and Lolo National Forests (USFS 2015a, pp. 9-27). On the Flathead, the RMRS trapped and radio-marked 7 lynx (3 females, 4 males) in the Flathead River watershed from 2010-2015, and surveys detected lynx in several other areas including the Salish Mountains, the

area just south of Glacier National Park, and in the vicinity of Hungry Horse Reservoir (USFS 2015a, pp. 10-11). The Swan Lake District in the southern part of the Flathead, along with the Seeley Lake District of the Lolo National Forest and the Lincoln District of the Helena National Forest, is part of the 6,070-km² (2,344-mi²) Southwestern Crown of the Continent, which was intensively surveyed from 2012-2014 by the Southwestern Crown Carnivore Monitoring Team (SCCMT 2014, entire). The SCCMT conducted snow track surveys and used hair snares, bait stations, and camera traps to detect lynx in 36 of the 82, 8 x 8 km (5 x 5 mi) grid cells they surveyed (SCCMT 2014, pp. 3, 17-20). The surveys resulted in collection of DNA that allowed identification of 18 individual lynx (5 females, 13 males), 13 of which were new to regional lynx databases (SCCMT 2014, pp. 3, 17-20), indicating recruitment of new individuals into this population, or immigration, or a combination of the 2.

On the Helena National Forest, few lynx have been detected outside the Lincoln District/Southwestern Crown area described above. In the south MacDonald Pass area, just south of this SSA unit and south of designated critical habitat, an individual male lynx was verified by DNA evidence over 4 winters (2007-2011), and an individual female was verified in the same area in the winter of 2008-2009 (Gehman *et al.* 2011, p. 21; USFS 2015a, p. 27). Other surveys on the Helena National Forest failed to detect lynx in the disjunct Big Belt and Elkhorn Mountains, although telemetry data indicated that 3 lynx released in Colorado passed through the Big Belts in 2004-2006 (USFS 2015a, pp. 26-27). Likewise, during snow tracking surveys on the Lolo National Forest in 2010-2011 (prior to the Southwestern Crown monitoring described above), lynx were also confirmed on the Seeley Lake District in the eastern part of the forest, but no lynx were documented on the Missoula or Ninemile districts, nor on the Superior and Plains/Thompson Falls districts in the western part of the forest (USFS 2015a, pp. 12-14). The USFS concluded that lynx presence in districts other than Seeley Lake is extremely rare and likely represents occasional dispersing lynx (USFS 2015a, p. 21).

On the Kootenai National Forest, RMRS research trapping and telemetry efforts continued to document the long-term presence of lynx from 2003-2012 (USFS 2015a, p. 10). On the Lewis and Clark National Forest, lynx are considered “still present” in the Rocky Mountain Front portion of the forest, which is within this geographic unit and designated critical habitat, and snow track surveys from 2010-2013 in the disjunct Little Belt and Crazy Mountains documented the continued absence of resident lynx in those ranges (USFS 2015a, pp. 25, 27-34). In Idaho, surveys in 2006-2007 by the Coeur d’Alene Tribe recorded 1 lynx detection in the Coeur d’Alene Mountains and 1 in the Saint Joe Mountains (Albrecht and Heusser 2009, entire). On the Idaho Panhandle National Forest, Multi-species Baseline Initiative (MBI) surveys in 2010-2014 detected 5 individual lynx (2 males, 3 females): 1 male in the Selkirk Mountains; 1 male and 2 females in the Purcell Mountains (and another 18 detections not identifiable to individual), and 1 female in the West Cabinet Mountains (Lucid *et al.* 2016, pp. 158-160). All detections were within 50 km (31 mi) of the Canada border, 3 detections were of incidentally-trapped lynx (2 in the West Cabinets released unharmed [1 with a radio collar] and 1 in the Purcells that died), and no lynx were detected in the Coeur d’Alene or Saint Joe Mountains (Lucid *et al.* 2016, p. 180). MBI follow-up surveys in 2015-2016 targeting areas where lynx were detected in 2010-2014 resulted in 89 lynx detections representing a minimum of 6 individual lynx; 1 in the Selkirks, 4 in

the Purcells (including camera images of an adult traveling with 2 young and later on the same camera an adult traveling with 1 juvenile), and 1 in the West Cabinets (IDFG 2017a, p. 5). No lynx were detected in the Saint Joe Mountains.

In summary, although the number of lynx in this geographic unit is uncertain, resident lynx appear to remain broadly distributed throughout much of the unit as evidenced by continued documentation of lynx in the research surveys described above. Genetic analyses and snow and camera surveys have verified continued reproduction and recruitment among lynx populations in this unit and also suggest some immigration may be occurring. The recent apparent absence of resident lynx in Garnet Mountains may indicate extirpation of a small resident population and a contraction in lynx distribution in the southern part of the unit, or it may reflect natural source-sink dynamics of a naturally ephemeral peripheral population in a mainland-island metapopulation structure. Lynx are rarely detected on surveys on other national forests (or parts of those above) that are outside but adjacent to this geographic unit (Patton 2006, entire; USFS 2105a, pp. 1-9, 25-34), suggesting that these areas lack the habitat features and/or landscape-level hare densities necessary to support resident lynx populations (79 FR 54818-54820).

Factors Affecting Current Conditions

Regulatory Mechanisms - Federal management activities (especially timber harvest and precommercial thinning, perhaps fire suppression) that occurred prior to listing and before implementation of current Federal regulatory mechanisms likely impacted some lynx habitats by altering the distribution and quality of hare habitats. However, because these activities occurred in low proportions of lynx habitat on Federal lands and impacts appear to have been localized, they were deemed a low-level threat to lynx at the time of listing (65 FR 16072-16076; 68 FR 40091-40095). Nonetheless, past Federal management activities may continue to influence the current quality and distribution of lynx habitats in some parts of this unit. For example, as described above in *Habitat Status* and *Lynx Status*, past timber harvest/management and associated road construction may have fragmented, reduced the amount, and altered the distribution of lynx habitats in the Garnet Mountains, perhaps contributing to the apparent recent loss of that area's ability to support resident lynx.

Currently, as described above and in section 3.1, all Federal and Tribal lands, most State lands, and large blocks of private or formerly-private land in this unit are managed for the conservation of lynx habitats, and much of the unit is in designated wilderness or other nondevelopmental land-use allocations. Regulatory mechanisms and conservation measures associated with these management strategies are intended to conserve and restore lynx and hare habitats across large landscapes and multiple ownerships. Although their effectiveness has not been quantitatively evaluated, and despite the potential extirpation of a small population in the Garnets, lynx habitats and resident lynx appear to remain well distributed throughout most of this unit.

Other regulations prohibit lynx trapping and require measures to reduce the likelihood of trapping lynx incidentally when legally trapping other species. Since the DPS was listed in 2000, 16 lynx are documented to have been incidentally trapped in Montana, with 13 of those occurring before 2008, when more protective regulations (e.g., lethal snares prohibited for bobcat sets, leaning pole sets limited to < 4" pole that must be 48" above ground for marten, fisher, and wolverine) were put in place (MTFWP 2016, pp. 5-10). Of the 16, 8 were released uninjured, 1 was released with an injury, and 7 were killed; all incidences of mortality occurred prior to 2008 and prior to the implementation of the more protective regulations (MTFWP 2016, p. 5). In Idaho, in addition to the 3 lynx incidentally trapped on the Idaho Panhandle National Forest from 2012-2014 (described above under *Lynx Status*), 1 other lynx was incidentally trapped in 2012 on the Salmon-Challis National Forest further south.

Although lynx are legally trapped in Canada adjacent to this unit in southern Alberta and southern British Columbia, trapping there is managed through regulated seasons and harvest levels, which are adjusted to avoid overexploitation, especially during the low phase of the hare-lynx population cycle (Environment Canada 2014, entire; Vashon 2015, pp. 5-6). Lynx harvest in Alberta varied from about 4,000 to 14,000 annually in the late 1970s and early 1980s, but declined to fewer than 2,000 for most years from 1984-2000, and restrictive quotas and season closures were implemented beginning in the late 1980s (Poole and Mowat 2001, pp. 16, 28). Similarly, harvests in British Columbia peaked at over 12,000 in the early 1960s and over 8,000 in the early 1970s, then declined to fewer than 2,000 for most years from the mid-1980s until the year 2000 (Hatler and Beal 2003, p. 2). Whether (and if so to what extent) trapping in Canada may influence lynx dispersal across the border and into this geographic unit is unknown; however, such dispersal was documented historically when harvest levels in Canada were much higher than under current management.

Climate Change - As elsewhere, increased temperatures, reduced snowpack, earlier snowmelt, and increased drought leading to increased fire all have been documented in this geographic unit (e.g., Hall and Fagre 2003, entire; Mote 2003b, entire; Fagre 2005, entire; Knowles *et al.* 2006, entire; Harvey *et al.* 2016, entire; Siren *in* Lynx SSA Team 2016a, pp. 14-15; Squires *in* Lynx SSA 2016, p. 20; Westerling 2016, entire). A number of potential impacts to lynx have been described, and climate projections suggest these impacts are likely to result in future loss and increased fragmentation and isolation of lynx and hare habitats and declining lynx populations in the DPS (Carroll 2007, entire; Gonzalez *et al.* 2007, entire; ILBT 2013, pp. 69-71; 79 FR 54810-54811; Lawler and Wilsey *in* Lynx SSA Team 2016a, pp. 15-16; Siren *in* Lynx SSA Team 2016a, p. 15; see also sections 3.2, and 5.2.3). Although climate change has probably already had some impact on lynx habitats in this geographic unit, and such impacts are likely to continue to occur, there currently is no evidence that climate change has had population-level effects or has reduced the unit's current ability to support persistent resident lynx populations. However, such impacts would be difficult to document and, as described under *Habitat Status*, above, lynx habitats in this unit are naturally highly-fragmented and hare densities, even in areas considered high-quality habitat for this DSP unit, often appear to barely meet the 0.5 hares/ha (0.2 hares/ac) threshold thought necessary to support resident lynx.

Therefore, even relatively minor impacts, especially to hare and lynx foraging habitats, may strongly influence lynx persistence in some parts of this unit.

Modeling vegetation and snow suitability for lynx across North America, Gonzalez *et al.* (2007, pp. 12, 15) indicated that boreal and temperate conifer forest biomes were broadly distributed across this geographic unit and that snow conditions suitable for lynx occurred with 90-95 percent probability from 1961-1990. (Future conditions based on this modeling are described in section 5.2.3). As described in section 3.2, climate change has also been implicated in recent increases in the frequency and intensity of outbreaks of boreal forest insect pests, with warmer winters resulting in increased insect survival and drought increasing conifer vulnerability to insects. This trend is expected to continue through the end of the century with continued climate warming (Bentz *et al.* 2010, pp. 607, 609). Although insect outbreaks have affected some parts of the DPS, no major outbreaks have been documented in lynx habitats in this unit (Lynx SSA Team 2016a, p. 41).

Vegetation Management - As elsewhere in the DPS range, timber harvest and related vegetation management (precommercial thinning and other silvicultural techniques designed to optimize forest products outputs; ILBT 2013, pp. 71-72) are the dominant land uses potentially affecting lynx habitats in this unit (68 FR 40075, 40092; 79 FR 54825). As described in section 3.3, these activities can reduce hare and lynx habitats by reducing horizontal cover and altering natural disturbance regimes and forest successional patterns. In this unit, precommercial thinning was shown to reduce short-term hare abundance (Griffin and Mills 2007, entire) and appeared to influence lynx movements (Squires *et al.* 2013, p. 192-194), and lynx rarely traveled across recent clearcuts or other large openings, especially in winter (Squires *et al.* 2010, p. 1654; ILBT 2013, p. 77). However, as described under *Habitat Status*, above, these activities on Federal lands, which account for most of the lands in this unit, occur only on lands with developmental allocations and historically appear to have impacted only a small proportion of potential lynx habitats in this unit (65 FR 16072; 68 FR 40093). Additionally, timber harvest levels on Federal lands in the West, including the Northern Rockies, and specifically with regard to "lynx forest types," had declined consistently and dramatically for a decade or longer prior to the DPS being listed (68 FR 40093), and have remained at levels much lower than those from most of the previous century. Despite some likely localized impacts, past vegetation management does not appear to have broadly diminished this unit's ability to support resident lynx, although, as described above, it may have contributed to the current absence of a small number of resident lynx from the Garnet Mountains. Also as described above, current vegetation management in this unit on all Federal, most State and Tribal, and some private lands, is conducted in accordance with formally amended USFS and BLM management plans, an approved State HCP, Tribal regulations, and conservation easements designed to avoid or minimize impacts to lynx habitats, especially important hare and lynx winter foraging habitats.

Wildland Fire Management - As described above in section 3.4, wildfire suppression in this unit, as elsewhere in the West, has likely had little impact on lynx habitats (65 FR 16074; 68 FR 40093-94; USFS 2007, pp. 18, 20; USFS 2008a, p. 11; ILBT 2013, p. 76). Also as described in that section, wildfire frequency, size, and intensity have increased in this geographic unit, where

about 15 percent (4,172 km² [1,611 mi²]) of the forest area in this unit burned from 2000-2013 (Squires *in* Lynx SSA Team 2016a, p. 20), likely in response to climate warming and related increases in drought conditions (e.g., Harvey *et al.* 2016, entire; Westerling 2016, entire). During the 2017 fire season alone, roughly 1,150 km² (444 mi²; over 4 percent of the unit) burned, including the Rice Ridge and Reef fires, which together burned over 690 km² (267 mi²) in the core of the Seeley Lake population's habitat and the site of long-term lynx research by the RMRS.¹⁹ Although these fires likely have reduced or will reduce lynx carrying capacity in some parts of this geographic unit, we expect such impacts to be temporary, with burned areas regenerating into high-quality lynx and hare habitats 20-40 years post-fire. Thus far, we are aware of no evidence that increased fire activity has permanently reduced lynx populations or diminished this geographic unit's ability to support resident lynx. However, with climate-driven elevated wildfire activity projected to continue into the future, such impacts are possible, depending on the location, timing, and extent of future fires (see section 5.2.3, below).

Habitat Loss and Fragmentation - As described above, the dominant land use in this unit, and that most likely to result in habitat loss and fragmentation, is timber harvest and associated vegetation management (e.g., precommercial thinning) and road construction. In the Northern Rocky Mountains, the forests upon which lynx depend have had less timber harvest, road construction, and have been modified much less than other drier forests (65 FR 16073), and these activities appear not to have had population-level impacts on lynx or to have measurably reduced the ability of this geographic unit to support resident lynx (with the possible exception of the Garnet Mountains). Few highways intersect lynx habitats in the Northern Rockies (ILBT 2013, p. 63) and there are few records of lynx killed by vehicle collisions in Montana (5) and Idaho (1; USFWS 2016c; MTFWP *unpubl. data*). Other potential sources of habitat loss and fragmentation include recreation, minerals/energy development, and backcountry roads and trails; these are all considered second tier anthropogenic influences (ILBT 2013, pp. 78-85) that are unlikely to exert population-level influences, despite potential impacts to individual lynx.

Other Factors - Connectivity/Immigration - As elsewhere in the range of the DPS, resident lynx populations in this geographic unit are thought to be influenced by connectivity with, and immigration of lynx from, populations in Canada (see section 2.2). However, whether, and if so to what the extent, the persistence of populations in this geographic unit may depend on regular or intermittent immigration of lynx from Canada remains uncertain, and historic, recent, and current immigration rates are unknown. This unit is directly connected to lynx habitats and populations in southwestern Alberta and southeastern British Columbia, where lynx habitats are also (like Montana and Idaho) patchily-distributed and generally support low hare densities, and where some lynx populations may be ephemeral and the persistence of others reliant on periodic immigration (Apps 2007, pp. 81, 95-104). Additionally, connectivity between this geographic unit and lynx habitats and populations in southern Alberta and southern British Columbia may be facilitated by only a few predicted corridors that extend south from the international border (Squires *et al.* 2013, pp. 187, 191-193).

¹⁹ <https://inciweb.nwcg.gov/state/27/0/>

Although lynx occurrence and harvest records in this geographic unit reflect the unprecedented irruptions of lynx from Canada into the northern contiguous United States in the early 1960s and early 1970s (McKelvey *et al.* 2000a, pp. 224-226, 232-242), there is no evidence of irruptions of lynx into this unit after the 1980s (Squires *in* Lynx SSA Team 2016a, p. 20). This is supported by lynx trapping records from Canada, which suggest that the magnitude of lynx population cycles in Alberta and British Columbia dampened dramatically after the early 1980s (McKelvey *et al.* 2000a, p. 226; Poole and Mowat 2001, p. 28; Hatler and Beal 2003, p. 2; Bowman *in* Lynx SSA Team 2016a, p. 13; also see Appendix 5, 2015 10 13 - 5, pp. 4-5²⁰).

A number of climate-mediated factors have been suggested as contributing to changes in the periodicity and amplitude of northern lynx and hare population cycles (see section 3.2), which would be expected to alter the timing and magnitude of irruptions of lynx from Canada into the contiguous United States. If lynx populations in this unit rely on immigration from Canada which is no longer occurring or has been substantially reduced relative to historical conditions, population declines and a reduced likelihood of persistence among resident populations would be expected. Although the extent to which this factor has influenced the current condition of lynx populations in this unit is unknown, the population growth rate estimated for the Seeley Lake area ($\lambda = 0.92$, declining trend 1999-2007; Squires *in* Lynx SSA Team 2016a, p. 20) may reflect a gradual decline of a resident lynx population that needs but is not receiving adequate immigration. In contrast, the growth rate estimated for the lynx population in the Purcell Mountains in the northwestern part of this unit ($\lambda = 1.16$, increasing trend 2003-2007; Squires *in* Lynx SSA Team 2016a, p. 20) suggests that the level of immigration, if necessary for demographic stability, has been adequate or that productivity and recruitment have been high enough to offset potentially diminished immigration. It is also possible that, despite the documented historical intermittent (cyclic) influxes of lynx from Canada into lynx populations in this geographic unit, immigration does not contribute meaningfully to the demographic stability of these populations. If that is the case, the estimated growth rates suggest that recruitment has failed to offset mortality in the Seeley Lake population but that it has more than done so in the Purcell Mountains population. However, Schwartz (2017, p. 4) noted that very low immigration rates (less than 1 female/year on average for a theoretical population of 100 lynx) could provide population stability or even growth, suggesting that the Seeley Lake population and perhaps other DPS populations are probably being sustained by low levels of undetected immigration. The growth rate estimates presented above assumed no immigration.

4.2.4 Unit 4 - North-central Washington

Unit Description: This geographic unit is located on the eastern side of the northern Cascade Mountain Range of north-central Washington in portions of Chelan and Okanogan Counties. It includes mostly Okanogan-Wenatchee National Forest lands as well as BLM lands in the Spokane District that were designated as critical habitat for lynx in 2014 (79 FR 54825). The unit also includes State Forest lands (portion of the Loomis State Forest) that were excluded from

²⁰ <https://www.fws.gov/mountain-prairie/es/species/mammals/lynx/SSA2016/Appendices/Appendix%205%20Presentation%20PDFs/2015%2010%2013%20-%205%20-%20Bowman%20Lynx%20Southern%20Canada.pdf>.

designation as critical habitat (79 FR 54825). It encompasses approximately 5,176 km² (1,988 mi²), with ownership that is 91.5 percent Federal (USFS, BLM), 8.2 percent State, and 0.3 percent private lands; there are no Tribal lands in this unit. This unit is about 200 km (125 mi) west of the Northern Montana/Northeastern Idaho geographic unit. This area was occupied by resident lynx when the DPS was listed and remains occupied currently. Evidence from recent research and DNA analysis shows lynx distributed within this unit, and breeding has been documented. Although researchers have fewer records in the portion of the unit south of Highway 20, this area contains boreal forest habitat and is thought to support resident lynx. Further, it is contiguous with lynx habitat north of Highway 20, particularly in winter when deep snows close Highway 20. The northern portion of the unit adjacent to the Canada border also appears to support few recent lynx records; however, it is designated wilderness and access to survey this area is difficult. This northern portion contains extensive boreal forest vegetation types and also likely supports resident lynx. Additionally, lynx populations exist in British Columbia directly north of this unit.

This geographic unit represents 58 percent of the 8,923-km² (3,445-mi²) Okanogan Lynx Management Zone (LMZ) identified by the WADFW (Stinson 2001, p. 16). Five smaller and relatively disjunct LMZs to the east of this geographic unit (Vulcan-Tunk, Kettle Range, The Wedge, Little Pend Oreille, and Salmo Priest) combined represent another 3,656 km² (1,412 mi²) of potential lynx habitat known or thought to have historically and perhaps recently supported a small number of lynx, at least intermittently. Among these, the Kettle Range LMZ was thought to support a small (likely fewer than 20 individuals) resident lynx population as recently as the late 1970s that may have been extirpated as a result of overharvest compounded by habitat changes (Stinson 2001, pp. 14-16; Koehler *et al.* 2008, p.1523; see Lynx Status, below).

Habitat Description: In the northern Cascades most lynx occurrences are associated with the Rocky Mountain Conifer Forest (Aubry *et al.* 2000, p. 379; McKelvey *et al.* 2000a, p. 246) at elevations between 1,400 m (4,593 ft) and 2,150 m (7,053 ft; McKelvey *et al.* 2000d, p. 322; Stinson 2001, p. 9). Within this area lynx primarily use forests dominated by Engelmann spruce, subalpine fir, or lodgepole pine on mild to moderate slopes (< 30°), and avoid Douglas-fir and ponderosa pine forests, forest openings, recently burned areas with sparse canopy and understory cover (< 10 percent), low elevations [less than 915 m (3,000 ft)], and steep slopes (> 30°; Koehler *et al.* 2008, pp. 1518, 1521; Maletzke 2004, pp. 16-17). Similar to the Northern Rocky Mountains, lynx habitat in the North Cascades is naturally fragmented (Koehler *et al.* 2008, p. 1523). As in other boreal forest systems, fires and insect outbreaks are major drivers of disturbance in this unit, but other factors, including wind and tree diseases, also contribute to natural disturbance regimes (Agee 2000, p. 47). Fire return intervals in the North Cascades range between approximately 100 to 250 years (Agee 2000, p. 50). Average annual snowfall is consistent throughout this unit and is approximately 291 cm (115 in)²¹.

Walker (2005, p. 20) estimated an average snowshoe hare density of 0.89 hares/ha (0.36 hares/ac) with a range of 0.03 to 4.85 hares/ha (0.01 to 1.94 hares/ac) in the North Cascades.

²¹ <https://snowfall.weatherdb.com/d/a/Washington>; accessed 4.27.2016.

The WADNR estimated snowshoe hare densities between 0.3 and 0.7 hares/ha (0.1 and 0.3 hares/ac) on the Loomis State Forest (WADNR 2006, p. 87). Koehler (1990a, p. 848) found snowshoe hares were the primary prey of lynx in the North Cascades, occurring in 23 of 29 (79 percent) lynx scats examined. The remains of red squirrels were identified in 24 percent of scats, which also included remains of other species including deer and mice. Similarly, Von Kienast (2003, p. 39) found snowshoe hares in 87 percent (40 of 46) of lynx scats in the North Cascades, while red squirrels were identified in 28 percent of scats.

Habitat Status: Lynx habitat in this geographic unit has been reduced and fragmented by multiple large wildfires over the past several decades that have likely caused a reduction, perhaps temporary, in the number of resident lynx in the unit (Lewis 2016, pp. 4-6; Lyons *et al.* 2016, entire; Maletzke *in* Lynx SSA Team 2016a, p. 21; see Lynx Status below). Several wildfires affected lynx habitat in the North Cascades during the middle 1990s and early 2000s: 1994 Whiteface Burn (15.5 km² [6 mi²]); 1994 Thunder Mountain Fire (36.9 km² [14.2 mi²]); 2001 Thirty-Mile Fire (25.7 km² [9.9 mi²]); and 2001 Farewell Fire (323 km² [125 mi²]; Vanbianchi 2015, p. 23). Subsequent to those fires and incorporating research on lynx habitat use, Koehler *et al.* (2008, p. 1522) estimated that the Okanogan LMZ (including this geographic unit) contained approximately 2,411 km² (930 mi²) of suitable lynx habitat, and that the other 5 LMZs in the northeastern corner of the state, combined, contained an additional 1,381 km² (533 mi²) of suitable habitat. More recent wildfires, including the 2006 Tripod Fire (706 km² [273 mi²]; Vanbianchi 2015, p. 23), have affected approximately 1,000 km² (386 mi²) of lynx habitat in the Okanogan LMZ (Maletzke *in* Lynx SSA Team 2016a, p. 21), and the Diamond Creek fire burned another 393 km² (152 mi²) in the northern part of this unit during July-October 2017, along with another 126 km² (49 mi²) across the border in southern British Columbia²².

Recently, Lewis (2016, pp. 4-6, fig. 3, table 2) estimated that about a third (3,130 km² [1,209 mi²]) of the total forested area in the Okanogan LMZ burned from 1992 to 2015, and that the amount of suitable lynx habitat in the LMZ similarly declined by 37 percent, from 2,581 km² (997 mi²) in 1996 to 1,630 km² (629 mi²) in 2014. In the Kettle Range, Lyons *et al.* (2016, p. 5) estimated that about 11 percent (360 km² [139 mi²]) of the LMZ burned from 2000 to 2015, and Lewis (2016, p. 6) estimated that the amount of suitable lynx habitat in the LMZ declined by about 7 percent, from 404 km² (156 mi²) in 1996 to 376 km² (145 mi²) in 2014. Cumulatively, Lewis (2016, p. 6) estimated that suitable lynx habitat in north-central and northeastern LMZs in Washington declined by 26 percent, from 3,770 km² (1,456 mi²) in 1996 to 2,790 km² (1,077 mi²) in 2014, with 97 percent of the losses occurring in the Okanogan LMZ and attributable to large wildfires over the past 25 years. This estimate does not include impacts of the 2017 Diamond Creek wildfire described above. These burned areas are expected to regenerate back into suitable lynx habitat, but it may take 10 to 40 years for that to occur (Lewis 2016, p. 5; Maletzke *in* Lynx SSA Team 2016a, p. 21), during which time the resident lynx population in this geographic unit will likely be at increased risk of stochastic demographic, genetic, and environmental effects.

²² <https://inciweb.nwcg.gov/incident/5409/>, accessed 10/25/2017.

As it is throughout the DPS range, maintaining connectivity with Canada is believed to be important to the conservation of resident lynx in this geographic unit (ILBT 2013, p. 65). Singleton *et al.* (2002, p. 46) reported broad landscape permeability for lynx between the northern Cascades and the Thompson River watershed in British Columbia. With no known barriers and lynx dispersal from this unit into Canada recently documented, connectivity with lynx populations and habitats in Canada currently appears functional (ILBT 2013, p. 65). Outside of this geographic unit, lynx habitat in the Kettle Range and the other northeastern LMZs is limited in size and potentially capable of supporting only a few lynx. Koehler *et al.* (2008, p. 1523) estimated the Kettle Range could support 10 to 23 lynx based upon a lynx density of 2.3 lynx/100km² and 400 km² (154 mi²) to 987 km² (381 mi²) of lynx habitat. However, that lynx density estimate was derived from research conducted in the Cascade Range within a large area of contiguous, high-quality habitat (Koehler 1990a, pp. 845, 847). Lynx habitat in the Kettle Range is much smaller and likely more fragmented, and may not be capable of supporting a similar density. The Kettle Range is also somewhat isolated from other lynx habitats in Washington and British Columbia. The Kettle Range is separated from the Cascades in Washington by low elevation valleys dominated by shrub-steppe and Douglas-fir and ponderosa pine forests (Koehler *et al.* 2008, p. 1523), and from British Columbia by the Kettle River Valley (Stinson 2001, p. 20) and a major highway corridor with associated wildlife fencing in British Columbia (Koehler *et al.* 2008, p. 1523). These natural topographic and anthropogenic features may impede lynx movement between the Kettle Range and the Cascades and British Columbia, perhaps reducing the likelihood of natural recolonization and re-establishment of a resident breeding population in the Kettle Range.

Lynx Status: In Washington, there is little information on the status of lynx prior to the early 1960s (Stinson 2001, p. 13) because lynx trapping records were not maintained in Washington prior to 1961. From 1960 to 1991 a total of 234 lynx was harvested in Washington, with the most (35 percent) lynx trapped in Ferry County, followed by Okanogan (23 percent) and Stevens (10 percent) counties (Stinson 2001, p. 13). Lynx were trapped relatively consistently in the Kettle Range in the 1960s, 1970s, and 1980s, with a total of 81 lynx harvested from 1961 through 1986 (Stinson 2001, p. 63). Beginning in 1978, trapping seasons for lynx in Washington were reduced to 1 month. In 1987 a restricted permit system was implemented, and in 1990 a statewide closure on lynx trapping was implemented (USFWS 2008a, p. 2). In 1993, lynx were classified by the Washington Fish and Wildlife Commission as a State threatened species (Stinson 2001, p. 22). In 2001, the WADFW considered lynx to be present in the Okanogan, Kettle Range, Little Pend Oreille, and Salmon-Priest LMZs; at that time lynx had not been detected in the Wedge LMZ since 1987 nor the Vulcan-Tunk LMZ since 1990 (Stinson 2001, p.15). In its October, 2016, *Periodic Status Review for the Lynx*, the WADFW recommended that the Washington Fish and Wildlife Commission uplist the lynx from a State threatened to a State endangered species because of: 1) observed range contraction in Washington following protection efforts; 2) the substantial loss of habitat in the last 20 years; and 3) the ongoing and anticipated threats to lynx population persistence (Lewis 2016, pp. iii; WADFW 2016, entire). In December, 2016, the Commission approved WADFW's review and adopted its recommendation to uplist lynx to endangered (WAFWC 2016, p. 3).

As elsewhere in the DPS, there are no reliable historical or current estimates of the number of resident lynx in this geographic unit. In 2001, based on data collected from lynx telemetry studies conducted in the Cascade Range during the 1980's, the WADFW estimated that Washington contained approximately 12,579 km² (4,857 mi²) of potential lynx habitat which it felt could theoretically support up to 238 lynx, including up to 149 lynx in the Okanogan LMZ (based on a lynx density of 2.5 lynx/100 km²; Stinson 2001, p. 16). However, based on professional opinions of individuals knowledgeable about lynx and lynx habitat and on surveys conducted as of 2000, the WADFW concluded that the State's lynx population almost certainly numbered fewer than 200 and perhaps fewer than 100 lynx at that time (Stinson 2001, p. 16). Koehler *et al.* (2008, p. 1523) later estimated there was approximately 3,800 km² (1,467 mi²) of suitable lynx habitat in Washington's 6 LMZs, potentially capable of supporting up to 87 resident lynx. This revised estimate of potential carrying capacity was based on a study investigating lynx habitat use in the Okanogan from 2002 to 2004, and used a lynx density estimate of 2.3 lynx/100 km² derived from a radio-telemetry study of lynx in the Cascades from 1985-1987 (Koehler 1990a, pp. 845-847). However, the study area from which the 2.3 lynx/100 km² density estimate reported by Koehler (1990a, p.847) was derived is located in an area of the northern Cascades known as the "Meadows". During the time of Koehler's study, the Meadows provided some of the best lynx habitat in Washington, whereas most other potential lynx habitat in Washington is lower in elevation and more highly fragmented (Walker 2005, pp. 3, 6). Thus, the lynx densities Koehler observed in his study area in the Meadows may not be applicable to other areas of potential lynx habitat in Washington, because as habitat becomes more fragmented and isolated, the carrying capacity for lynx likely declines. Therefore, applying Koehler's estimated density uniformly throughout Washington would likely overestimate the number of resident lynx potentially supported in Washington.

More recently, Lewis (2016, pp. 5-6) estimated that wildfires over the last several decades (see [Habitat Status](#) section above) have reduced the carrying capacity of the Okanogan LMZ by 37 percent, from 43 females (86 total lynx assuming similar numbers of males and females) in 1996 to 27 females (54 total lynx) in 2014. The author estimated a minor decline in carrying capacity in the Kettle Range LMZ from 8 females (16 total lynx) in 1996 to 7 females (14 total lynx) in 2014. Overall, Lewis (2016, p. 6) estimated that suitable lynx habitat in north-central and northeastern LMZs in Washington declined by 26 percent from 1996 to 2014, with most of the losses resulting from large wildfires in the Okanogan LMZ, and that lynx carrying capacity in the State declined by 29 percent from 58 females (116 total lynx) to 41 females (82 total lynx) over that time period. However, considering a dramatic increase in female home range size (from about 39 km² [15 mi²] during 1990-2002 to 91 km² [35 mi²] by 2014), likely a result of fire-driven habitat loss and fragmentation, Maletzke (*in* Lynx SSA Team 2016a, p. 21) suggested that the carrying capacity of the Okanogan LMZ alone, which encompasses this geographic unit, may have declined from 90-115 females (180-230 total resident lynx) to as few as 27 females (54 total resident lynx) currently. Maletzke's estimate suggests a much larger (70 to 77 percent) potential decline in carrying capacity in this LMZ and, therefore, in the North-central Washington geographic unit. Because of these habitat impacts, limited demographic information, and remaining uncertainties (e.g., immigration/emigration rates, changes in snowpack, disease, lynx population status and impacts of trapping in southern British Columbia, and habitat corridor

stability between British Columbia and this unit; WADFW 2017, p. 3), the Washington Department of Fish and Wildlife recently submitted, and the State Fish and Wildlife Commission adopted, a proposal to uplist lynx from threatened to endangered within the State.

From 1985 to 1987, Koehler (1990a, entire) monitored the movements of 5 adult male and 2 adult female radio-collared lynx in the Cascades of north-central Washington. Results of the study indicated average female home range size was 39 km² (15 mi²) and average male home range size was 69 km² (27 mi²). Based on occupancy of the 640 km² study area by 15 adult lynx, adult lynx density was estimated to be 2.3 adults/100 km². Annual adult survival rates of the radio-collared lynx were 0.73 in 1986 and 1.00 in 1987, and kitten mortality was high at 88 percent with only 1 of 8 known kittens surviving its first year (Koehler 1990a, p. 847).

Factors Affecting Current Condition

Within Washington, the vast majority of lynx habitat is administered by the Okanogan-Wenatchee (OWNF) and Colville (CNF) National Forests. The North Cascades (i.e., the Okanogan LMZ in north-central Washington), which supports the only known, long-term persistent lynx breeding population in Washington, and within which critical habitat was designated for lynx in 2014 (79 FR 54782), is administered by the OWNF. Subsequent to listing lynx under the ESA, the Forest Service entered into a Conservation Agreement (CA) with the Service in 2000 (USFS and USFWS 2000, entire), which was revised and extended in 2006 (USFS and USFWS 2006, entire). The CA committed the OWNF and CNF to use the Lynx Conservation Assessment and Strategy (LCAS) for management of lynx and its habitat on their ownerships, and will remain in place until the forests amend or revise their individual LRMPs.

In Washington, and the north Cascades specifically, it appears that the single threat for which lynx were listed under the ESA (i.e., inadequacy of Federal regulatory mechanisms) has largely been addressed through the development of the LCAS, and CA between the USFS and Service, which commits the USFS, specifically for Washington the OWNF and CNF, to use the LCAS in the management of lynx habitat on National Forest System lands and when designing and implementing projects within LAUs.

The WADNR manages approximately 4 percent of the lynx habitat within portions of each of the delineated LMZs (WADNR 2006, p.9) in Washington State, including the Loomis State Forest that is located in the north Cascades within the Okanogan LMZ. In 1996, the WADNR developed and implemented a Lynx Habitat Management Plan (1996 Lynx Plan) in response to listing of the lynx as a State threatened species by Washington State (WADNR 1996, entire). After the DPS was Federally listed as threatened, the WADNR in 2006 modified its Lynx Habitat Management Plan to incorporate new science and management standards and guidelines to avoid the incidental take of lynx in accordance with the ESA (WADNR 2006, entire). These standards and guidelines address maintenance of lynx denning and foraging habitat, as well as habitat connectivity within and between LAUs and lynx populations within Washington (i.e., LMZs) and Canada.

For example, the WADNR 2006 Lynx Plan includes, among other things: (1) Encouraging genetic integrity at the species level by preventing bottlenecks between British Columbia and Washington by limiting size and shape of temporary non-habitat along the border and maintaining major routes of dispersal between British Columbia and Washington; (2) Maintaining connectivity between subpopulations by maintaining dispersal routes between and within zones and arranging timber harvest activities that result in temporary non-habitat patches among watersheds so that connectivity is maintained within each zone; (3) Maintaining the integrity of requisite habitat types within individual home ranges by maintaining connectivity between and integrity within home ranges used by individuals and/or family groups; and (4) Providing a diversity of successional stages within each LAU and connecting denning sites and foraging sites with forested cover without isolating them with open areas by prolonging the persistence of snowshoe hare habitat and retaining coarse woody debris for denning sites. The 2006 Lynx Plan also describes how WADNR will monitor and evaluate the implementation and effectiveness of the plan. The WADNR has been managing for lynx for almost 2 decades, and the Service has concluded that the management strategies implemented are effective. In the 2014 final revised critical habitat designation, we determined that the benefits of excluding lands managed in accordance with the WADNR 2006 Lynx Plan outweighed the benefits of including them in the designation, and that doing so would not result in extinction of the species (extirpation of the DPS; 79 FR 54834–54835).

In summary, recent wildfires have, perhaps temporarily, eliminated or reduced the quality of over 40 percent of the higher-quality lynx habitat within the North Cascades (Lewis 2016, pp 4-6; Maletzke *in* Lynx SSA Team 2016a, p. 21), which has reduced lynx carrying capacity and significantly affected the status of and current viability of the lynx population within this geographic unit. This geographic unit likely supports fewer resident lynx currently than it did historically, making the current, smaller population more vulnerable to environmental, demographic, and genetic stochasticity and to large catastrophic events (Lewis 2016, p. 5). Recent wildfire severity, extent, and intensity in lynx habitat within this geographic unit may have been influenced by climate change (Westerling *et al.* 2006, pp. 942-943), and as discussed in chapter 5, climate change may similarly affect the future viability of lynx within this geographic unit.

4.2.5 Unit 5 - Greater Yellowstone Area

Unit Description: This geographic unit includes the parts of southwestern Montana and northwestern Wyoming the Service designated as critical habitat (Unit 5) for lynx in 2014 (79 FR 54825-54826). It encompasses approximately 23,691 km² (9,147 mi²) in portions of Carbon, Gallatin, Park, Stillwater, and Sweetgrass Counties in Montana; and Fremont, Lincoln, Park, Sublette, and Teton Counties in Wyoming, with ownership that is 97.5 percent Federal (USFS, NPS, and BLM); 2.2 percent private; and 0.3 percent State. This unit includes parts of Grand Teton and Yellowstone national parks and the Bridger-Teton, Custer-Gallatin, and Shoshone National Forests, and lands managed by the BLM's Kemmerer and Pinedale Districts. It includes parts of the Absaroka, Beartooth, Gallatin, Gros Ventre, Salt River, Teton, Wind River, and Wyoming mountain ranges. This unit is not directly connected to lynx habitats and

populations in Canada or to other DPS populations, although lynx dispersing from the north likely arrived intermittently into the area historically and, more recently, some lynx released into Colorado traveled into and through this unit (Devineau *et al.* 2010, p. 526; Ivan 2017, entire; details below). Relative to other DPS lynx populations, this unit is about 145 km (90 mi) southeast of the Northwestern Montana/Northeastern Idaho unit, and roughly 400 km (250 mi) northwest of the Western Colorado geographic unit.

Habitat Description: In northwestern Wyoming and the GYA, lynx are generally associated with Engelmann spruce-subalpine fir and lodgepole pine of the Rocky Mountain Conifer Forest vegetation class, as described above (Section 4.2.3) for northwestern Montana, although these habitats, and thus lynx, typically occur at higher elevations (2,000-3,000 m [6,550-9,850 ft]) in the GYA (McKelvey *et al.* 2000a, p. 245; ILBT 2013, p. 60). Potential lynx habitat in much of the GYA is naturally marginal (patchier and composed in many places of drier forest types), with fewer shrubs and a more open understory, and generally very low to marginal hare densities, resulting in a spatially-limited distribution of lynx with large home ranges (Squires *et al.* 2003, pp. 5, 12-13; 68 FR 40090; 71 FR 66010, 66029; 74 FR 8624, 8643–8644; Hodges *et al.* 2009, entire; Berg and Gese 2010, p. 1750; 79 FR 54796; Lynx SSA Team 2016a, p. 45). Among the 3 national forests that contribute lands to this geographic unit, potential lynx habitat was mapped on about 42 percent of the total national forest area (both inside and outside this unit; USFWS 2007, pp. 32, 95, 122-123).

In Yellowstone National Park, 7,732 km² (2,985 mi²; about 86 percent of the park) is considered “lynx forest types” (65 FR 16073), but only 2,784 km² (1,075 mi²; 31 percent of the park, 36 percent of lynx forest types) is estimated to be potential lynx habitat (68 FR 40086). However, hares were completely absent from more than 36 percent of surveyed stands in Yellowstone National Park, and 96 percent had estimated hare densities below the 0.5 hare/ha threshold thought necessary to support resident lynx (Hodges *et al.* 2009, pp. 870, 873-877). In contrast, estimated hare densities were ≥ 0.48 hares/ha (0.19 hares/ac) in all surveyed stands on the Bridger-Teton National Forest in the southern portion of the GYA, with highest densities (1.7 hares/ha [0.69 hares/ac]) in 30-70-year-old regenerating lodgepole pine stands with dense horizontal cover, and densities of 1.2-1.6 hares/ha (0.49-0.65 hares/ac) in mature multi-story spruce-fir and mixed spruce-fir (containing aspen or lodgepole pine) stands (Berg *et al.* 2012, p. 1483). In the central Wyoming Range in the southern part of this unit, hare tracks were more abundant in seral aspen stands with a significant spruce-subalpine fir component than in aspen stands with little or no spruce-fir, and hares appeared to be absent from pure aspen stands except where they bordered spruce-fir areas (Endeavor Wildlife Research 2009, p. 4). The only lynx den sites described for this unit (the natal den and a subsequent maternal den of 1 female in 1998) occurred in a mature subalpine fir-lodgepole pine forest in the Wyoming Range, where coarse woody debris and high sapling density provided dense horizontal cover (Squires and Laurion 2000, pp. 346-347).

Average annual snowfall in this unit ranges from about 127 cm (50 in) in Bozeman and 556 cm (219 in) in West Yellowstone, Montana, on the northern and northwestern peripheries of the unit, respectively, to 280-310 cm (110-122 in) in Alpine, Dubois, and Jackson, WY near the central and southern peripheries, with most snow falling from November to March in each

place²³. In potential lynx habitats on the Bridger-Teton National Forest in the southern half of this unit, deep snow persisted from late October through May (Berg *et al.* 2012, p. 1481).

Habitat Status: Potential lynx habitats in this unit are currently designated as critical habitat in accordance with the ESA. Over 97 percent (23,109 km² [8,922 mi²]) of this unit is in Federal ownership, including 18,877 km² (7,292 mi²) in national forests under USFS management, 3,944 km² (1,523 mi²) in national parks managed by NPS, and 271 km² (105 mi²) managed by BLM. As described above in section 3.1.1, USFS lands in this unit are managed in accordance with the NRLMD, which formally amended all forest plans to adopt and implement lynx conservation measures (USFS 2007, pp. 8-30 and Attachment 1, pp. 1-9) that were developed based on the scientific findings and recommendations of the LCAS (Ruediger *et al.* 2000, pp. pp. 7-1 - 7-18). Similarly, the BLM in 2008 and 2010 revised its RMPs for the Pinedale and Kemmerer districts, respectively, to include conservation measures and BMPs for lynx based on the LCAS (BLM 2008, pp. A18-10 - A18-15; BLM 2010, pp. A-9 - A-12). On lands with developmental land-use allocations, these amended forest plans and the revised BLM RMPs provide guidance on the kinds of activities that can and cannot be implemented in important lynx habitats and thresholds for the proportions of lynx habitat in LAUs that can be in an unsuitable state at any given time and how much can be converted from suitable to (temporarily) unsuitable over particular time frames. Implementation of these plans has likely benefitted lynx by providing a consistently-applied framework for conserving and restoring important hare and lynx habitats.

As elsewhere in the DPS (Squires *et al.* 2010, p. 1656; ILBT 2013, pp. 20, 27), winter foraging habitat is likely the most limiting habitat for lynx in this unit, and denning habitat is not thought to be limiting. Standards, guidelines and BMPs in the NRLMD and in revised BLM plans restrict vegetation management activities that could reduce winter snowshoe hare habitat and direct the creation or retention of coarse woody debris in areas where denning habitat may be lacking (USFS 2007, Attachment 1, pp. 2-5; BLM 2008, pp. A18-10 - A18-15; BLM 2010, pp. A-9 - A-12). Snow conditions in this unit also appear to remain suitable to allow lynx to outcompete other terrestrial hare predators. Gonzalez *et al.* (2007, pp. 4-7) modeled snow suitability across North America, showing that most of this geographic unit has a 95 percent probability of providing snow cover conditions consistent with historical lynx occurrence records (Gonzalez *et al.* 2007, p. 12).

This unit includes substantial areas in nondevelopmental land-use allocations, including (in addition to Yellowstone and Grand Teton national parks) the Absaroka-Beartooth, Bridger, Gros Ventre, Lee Metcalf, Northern Absaroka, Teton, and Washakie designated wilderness areas. Among the 3 national forests that contribute to this unit, 75 percent of potential lynx habitat is in designated wilderness or roadless areas (USFWS 2007, p. 34). Management activities in these areas are unlikely to adversely impact lynx and hare habitats. Large parts of Yellowstone National Park burned in the extensive wildfires of 1988. Although the extent to which those fires may have impacted potential lynx habitats is uncertain, some of the burned areas may soon reach a stage of regeneration capable of supporting increased densities of hares, perhaps

²³ <https://snowfall.weatherdb.com/d/a/Montana>; accessed 8.17.2016.

increasing the likelihood that lynx could reestablish and maintain home ranges in some parts of the park (Lynx SSA Team 2016a, p. 45). Because non-Federal lands make up less than 3 percent of lynx habitats in this unit, it is unlikely that activities on those lands have impacted lynx populations or meaningfully influenced the unit's current capacity to support resident lynx.

Overall, although naturally fragmented and patchily-distributed, potential lynx habitat in this geographic unit appears to be largely intact relative to historical conditions and disturbance regimes, with only a small proportion apparently impacted by past management (timber harvest and precommercial thinning) activities (65 FR 16072). Despite some likely localized impacts of past timber management and infrastructure (e.g., highway, railroad) development, past management activities do not appear to have diminished this unit's ability to support resident lynx or to have created barriers to lynx movement, or to have had other landscape- or population-level effects.

In summary, much of this geographic unit occurs in national parks, designated wilderness and roadless areas, or other nondevelopmental land-use allocations, where management activities with the potential to adversely affect lynx habitat generally do not occur. Almost all lands with developmental land-use allocations in this unit are managed by the USFS to conserve and maintain lynx and hare habitats under management plans that were formally revised in 2007 in accordance with the NRLMD and based on the scientific findings and conservation recommendations of the LCAS. A small proportion of lands with developmental allocations occurs on BLM lands where management plans also were revised recently (2008 and 2010) to adopt conservation measures identified in the LCAS. Implementation of these USFS and BLM plans likely precludes landscape-level management-related adverse impacts to the vast majority of existing lynx and hare habitats in this unit. Nonetheless, past management activities that occurred prior to implementation of current regulations and other conservation efforts may exert continuing influence on current habitat quality in some places. Additionally, because lynx habitats in this unit are naturally highly-fragmented and, in most places, support low landscape-level hare densities, relatively minor impacts, especially to hare and lynx winter foraging habitats, may strongly influence lynx persistence in some parts of this unit.

Lynx Status: There are no reliable estimates of the historical or current number of resident lynx in this unit. As described in section 2.3.2.2 above, the historical record and recent research show that the GYA has supported resident lynx at least occasionally, but it is unclear whether the area consistently supported a persistent resident population over time or whether it naturally supported resident lynx only intermittently. Most historical and recent verified lynx records are from the southern portion of this unit in the Gros Ventre, Salt River, Wind River, and Wyoming mountain ranges in the Bridger-Teton National Forest. Reeve *et al.* (1986a, entire; 1986b, entire), who compiled all lynx records state-wide in Wyoming from 1856-1986, reported 22 verified ("certain") records and over 200 unverified ("probable") records based on trapping reports and observations of animals or tracks (Reeve *et al.* 1986a, pp. 64-70. Most records were from the northwestern corner of the State (Reeve *et al.* 1986a, pp. 28-29; 1986b, pp. 6-9), which overlaps much of the GYA geographic unit. McKelvey *et al.* (2000a, pp. 229-230) reported 30 verified records for Wyoming, including those in Reeve *et al.* as well as 2 resident lynx, a male

and a female, who were trapped, radio-marked, and monitored in the Wyoming Range over several years beginning in 1996 and who produced 6 kittens over 2 years. The female had 4 kittens in 1998 and 2 in 1999, though none of the kittens survived to independence, and the female died of starvation in March 2000 (Squires and Laurion 2000, p. 346; Squires *et al.* 2001, pp. 9, 26). The female's home range averaged 50 km² (19 mi²) over the 3 years she was monitored, and the male's averaged 824 km² (318 mi²) over 5 years (Squires *et al.* 2003, pp. 12-13). The male also made multiple long-distance exploratory movements (up to 728 km [452 mi], including multiple highway crossings) over 3 successive years (Squires *et al.* 2003, pp. 13-16; Squires and Oakleaf 2005, entire).

As described in section 2.3.2.2, several sources reported accounts of numerous lynx being trapped in the Wyoming Range in the early 1970s. However, nearly all these records are unverified and the various anecdotal reports provide conflicting numbers and years in which lynx were purportedly trapped. These conflicting anecdotal reports illustrate compellingly why only verified records are appropriate for evaluating historical lynx distribution (McKelvey *et al.* 2000a, pp. 208-210; 2008, pp. 553-554). Even if these anecdotal records were accurate, the large numbers of lynx reported in the early 1970s correspond to the second of 2 well-documented and unprecedentedly large irruptions of lynx from Canada into the northern contiguous United States, when dispersing/transient lynx occurred temporarily in many parts of the DPS range (McKelvey *et al.* 2000a, pp. 232-242). That the sudden increase in lynx suggested by these anecdotal records would have reflected a pulse of dispersing lynx associated with that large irruption is more plausible than the notion that a previously undocumented resident lynx population suddenly and simultaneously became vulnerable to trapping in only a handful of winters.

Other surveys, however, resulted in verified detections of a small number of lynx in the southern portion of this unit from 1999-2009, with records most consistent in the Wyoming Range, Togwotee Pass, Union Pass, the Bondurant Corridor, and in the Gros Ventre Range (Squires *et al.* 2001, pp. 9-14; Squires *et al.* 2003, pp. 9-11, 29-31; Endeavor Wildlife Research 2008, 2009, entire; Berg 2016, *pers. comm.*; Squires *in* Lynx SSA Team 2016a, pp. 20-21). At least 9 radio-marked lynx released in Colorado subsequently moved into or through the GYA unit from 1999-2010, with locations of several of these lynx concentrated in areas used previously by the native male and female described above (Devineau *et al.* 2010, p. 526; Hanvey 2016, *pers. comm.*; Ivan 2017, entire). In winter 2004-05, a male and female, both released in Colorado in spring 2004, occupied overlapping areas on the east side of the Wyoming Range (Ivan 2017, p. 3, figs. 20, 24). During the 2006 breeding season, a male and a female, both also released in Colorado in 2004, occupied overlapping areas farther north near Pinnacle Buttes along Highway 287 (Ivan 2017, p. 3, figs. 21, 23). However, there is no evidence that either of these pairs bred or that either female denned or produced kittens (Ivan 2017, p. 3). On the Shoshone National Forest in the northeastern part of this unit, analysis of DNA collected during winter surveys confirmed 7 lynx snow tracks in winter 2005/06 and a single track in 2006/07 (Endeavor Wildlife Research 2008, p. 2; Berg 2016, *pers. comm.*). Overall, during the 4 winters of 2004-05 through 2007-08, 26 snow tracks on the Bridger-Teton and Shoshone National Forests were confirmed by DNA analyses to be from 5 individual lynx (3 males, 2 females). One of the males had

previously been documented in Yellowstone National Park (see below). The other 2 males and both females were lynx that had been released in Colorado (Pilgrim 2016, *pers. comm.*).

Verified records of lynx are less common elsewhere in this unit, including in Yellowstone and Grand Teton national parks and the Custer-Gallatin National Forest. There were no verified records of lynx in Yellowstone National Park from 1920-1999 (McKelvey *et al.* 2000a, p. 230); however, surveys in 2001-2004 documented at least 3 individual lynx, including 2 kittens, in the eastern part of the park (Murphy *et al.* 2006, entire). On the Custer-Gallatin National Forest in Montana in the northern part of the unit, a single female was detected over 6 consecutive winters (2003/2004 - 2008/2009) but not subsequently (Gehman *et al.* 2010, pp. 2-4), and it appears that she did not encounter a male or produce kittens during the 6 years she was detected (Gehman *et al.* 2010, p. 4).

Recent surveys and research-related trapping efforts have failed to detect lynx in this unit after 2010 (79 FR 54791; Squires *in* Lynx SSA Team 2016a, pp. 20-21, 45; Hanvey 2016, *pers. comm.*). As discussed above and in section 2.3.2.2, it is uncertain whether this unit historically supported a small but persistent resident population that was recently extirpated, or if it historically and recently supported resident lynx only intermittently. Given the protected conservation status of millions of acres in this unit, its apparent recent inability to support resident lynx may be a reflection of naturally marginal and patchy habitats and relatively low hare abundance in much of the unit, resulting in only an intermittent ability of this unit to support resident lynx (Lynx SSA Team 2016a, p. 57). Conversely, the characteristics described above suggest that relatively small impacts could shift potential habitats in this unit from just barely able to support a persistent resident population to incapable of doing so. Further, the available evidence suggests that if this unit did support a persistent population, it was very likely a very small one, which would be more vulnerable to extirpation as a result of demographic, environmental, and genetic stochasticity, catastrophic events (McKelvey *et al.* 2000b, pp. 23-29), or a combination of these factors.

Factors Affecting Current Conditions

Regulatory Mechanisms - As described above for Unit 3, Federal management activities (e.g., timber harvest and precommercial thinning, perhaps fire suppression) that occurred prior to listing and before implementation of current Federal regulatory mechanisms likely impacted some lynx by altering the distribution and quality of hare and lynx habitats. However, because these activities occurred in low proportions of lynx habitat on Federal lands and impacts appear to have been localized, they were deemed a low-level to threat to lynx at the time of listing (65 FR 16072-16076; 68 FR 40091-40095). Nonetheless, past Federal management activities may continue to influence the current quality and distribution of lynx habitats in some parts of this unit. Current regulatory mechanisms and conservation measures associated with recently amended or revised Federal management plans are intended to conserve and restore lynx and hare habitats across large landscapes. Although their effectiveness has not been quantitatively evaluated, they have almost certainly reduced significantly the potential for adverse management-related impacts to lynx habitats in this unit.

Lynx trapping has been prohibited in Wyoming since 1973 (79 FR 54794) and in Montana since 1999 (MTFWP 2016, p. 7) and, as described in section 3.1.2, both states require measures to reduce the likelihood of trapping lynx incidentally when legally trapping other species. Since the DPS was listed in 2000, no lynx are documented to have been incidentally trapped in the Montana portion of this unit (MTFWP 2016, pp. 5-10) and we are aware of no incidental captures in northwestern Wyoming since listing.

Climate Change - As elsewhere, increased temperatures, reduced snowpack, earlier snowmelt, and increased drought leading to increased fire all have been documented in this geographic unit (e.g., Mote *et al.* 2005, entire; Pederson *et al.* 2013, entire; Riley *et al.* 2013, entire; Dennison *et al.* 2014, entire; USEPA 2015, entire; Harvey *et al.* 2016, entire; Siren *in* Lynx SSA Team 2016a, pp. 14-15; Westerling 2016, entire). A number of potential impacts to lynx have been described, and climate projections suggest these impacts are likely to result in future loss and increased fragmentation and isolation of lynx and hare habitats and declining lynx populations in the DPS (Carroll 2007, entire; Gonzalez *et al.* 2007, entire; ILBT 2013, pp. 69-71; 79 FR 54810-54811; Lawler and Wilsey *in* Lynx SSA Team 2016a, pp. 15-16; Siren *in* Lynx SSA Team 2016a, p. 15; see also sections 3.2, and 5.2.3). Although climate change has probably already had some impact on lynx habitats in this geographic unit, and such impacts are likely to continue to occur, there currently is no evidence that climate change has had population-level effects or has reduced the ability of this unit to support persistent resident lynx populations. However, such impacts would be difficult to document and, as described under *Habitat Status*, above, lynx habitats in this unit are naturally highly-fragmented and hare densities low in some places. Therefore, relatively minor impacts, especially to hare and lynx foraging habitats, may strongly influence lynx persistence in some parts of this unit.

Modeling vegetation and snow suitability for lynx across North America, Gonzalez *et al.* (2007, pp. 12, 15) indicated that boreal and temperate conifer forest biomes were broadly distributed across this geographic unit and that snow conditions suitable for lynx occurred with 95 percent probability from 1961-1990. (Future conditions based on this modeling are described in section 5.2.5). As described in section 3.2, climate change has also been implicated in recent increases in the frequency and intensity of outbreaks of boreal forest insect pests, with warmer winters resulting in increased insect survival and drought increasing conifer vulnerability to insects. This trend is expected to continue through the end of the century with continued climate warming (Bentz *et al.* 2010. pp. 607, 609).

Vegetation Management - The influence of vegetation management on the current condition of lynx and habitats in this unit is described above under Habitat Status and *Regulatory Mechanisms*, above.

Wildland Fire Management - As described above in section 3.4, wildfire suppression in this unit, as elsewhere in the West, has likely had little impact on lynx habitats (65 FR 16074; 68 FR 40093-94; USFS 2007, pp. 18, 20; USFS 2008a, p. 11; ILBT 2013, p. 76). Also as described in that section, wildfire frequency, size, and intensity have increased in this geographic unit, likely in response to climate warming and related increases in drought conditions (e.g., Dennison *et al.* 2014, entire; Harvey *et al.* 2016, entire; Westerling 2016, entire), with most large, stand-

replacing fires having occurred in the northern part of the unit, in Yellowstone National Park (see Harvey *et al.* 2016, fig. 1). Despite this increase, we are aware of no evidence that increased fire activity in the unit has thus far impacted resident lynx populations or reduced this unit's ability to continue to support resident lynx.

Habitat Loss and Fragmentation - As described above, the dominant land use in this unit, and that most likely to result in habitat loss and fragmentation, is timber harvest and associated vegetation management (e.g., precommercial thinning) and road construction on lands with developmental allocations. Much of this unit occurs in national parks, designated wilderness and roadless areas, or other nondevelopmental allocations. Even in areas with developmental allocations, the moist subalpine forests important to lynx have had less timber harvest and road construction, and have been modified much less than other drier forests (65 FR 16073). These activities appear not to have had population-level impacts on lynx or to have measurably reduced the ability of this geographic unit to support resident lynx. Few highways intersect lynx habitats in the Northern Rockies (ILBT 2013, p. 63) and there are few records of lynx killed by vehicle collisions in Montana (5) and Wyoming (1 [a Colorado-released lynx]; USFWS 2016c). Other potential sources of habitat loss and fragmentation include recreation, minerals/energy development, and backcountry roads and trails; these are all considered second tier anthropogenic influences (ILBT 2013, pp. 78-85) that are unlikely to exert population-level influences, despite potential impacts to individual lynx.

Other Factors - Connectivity/Immigration - As elsewhere in the range of the DPS, resident lynx populations in this geographic unit are thought to be influenced by connectivity with, and immigration of lynx from, populations in Canada (see section 2.2). However, whether, and if so to what the extent, the persistence of populations in this geographic unit may depend on regular or intermittent immigration of lynx from Canada remains uncertain, and historic, recent, and current immigration rates are unknown. Although this unit is not directly connected to lynx habitats and populations in Canada or elsewhere in the contiguous United States, no barriers to lynx dispersal from the north have been identified, and 9 lynx released in Colorado are known to have dispersed northward into and through this unit (Devineau *et al.* 2010, p. 526; Ivan 2017, entire), demonstrating that dispersal between the southern and northern Rockies is possible. As described above in Lynx Status, the large number of lynx reportedly trapped from a small area of the Wyoming Range in the early 1970s (Squires and Laurion 2000, p. 338) may suggest dispersers associated with the irruption of many lynx from Canada into the northern contiguous United States documented at that time (McKelvey *et al.* 2000a, pp. 235-242). No subsequent pulses of lynx dispersing from the north have been documented, and lynx trapping records suggest that the magnitude of lynx populations cycles in Alberta and British Columbia, the most likely source of lynx dispersing southward into this unit, dampened dramatically after the early 1980s (McKelvey *et al.* 2000a, p. 226; Bowman *in* Lynx SSA Team 2016a, p. 13; also see Appendix 5, 2015 10 13 - 5, pp. 4-5²⁴).

²⁴ <https://www.fws.gov/mountain-prairie/es/species/mammals/lynx/SSA2016/Appendices/Appendix%205%20Presentation%20PDFs/2015%2010%2013%20-%205%20-%20Bowman%20Lynx%20Southern%20Canada.pdf>.

As described in section 3.2, a number of climate-mediated factors have been suggested as contributing to changes in the periodicity and amplitude of northern lynx and hare population cycles, which could alter the timing and magnitude of irruptions of lynx from Canada into the contiguous United States. If lynx populations in this geographic unit rely on immigration from Canada which is no longer occurring or has been substantially reduced relative to historical conditions, population declines and a reduced likelihood of persistence among resident populations would be expected. Although the extent to which this factor has influenced the current condition of lynx populations in this unit is unknown, it is possible that it has contributed to the recent apparent loss of resident lynx from this unit.

4.2.6 Unit 6 - Western Colorado

Unit Description - This geographic unit includes parts of the Southern Rocky Mountains of western Colorado. It encompasses approximately 25,294 km² (9,766 mi²) of potential lynx habitat distributed west of US Interstate 25, with ownership that is 90 percent Federal (85 percent USFS, 3 percent BLM, 2 percent NPS), 9 percent private, and < 1 percent State. When it listed the DPS, the Service identified 26,305 km² (10,156 mi²) of potential lynx habitat in the Southern Rockies (i.e., western Colorado and south-central Wyoming; [65 FR 16052]). In 2003, we estimated 31,027 km² (12,419 mi²) of potential habitat within that area (68 FR 40076). Ivan *et al.* (2011e, entire) developed a predictive map of lynx habitat by using telemetry location data collected during CPWs lynx monitoring, and then estimated the amount of habitat associated with a high probability of detecting lynx. Our review of the vegetative characteristics of CPW's predictive map detected large areas of spruce-fir habitats that were excluded by their presentation of the habitat associated with the top 20 percent of predicted use (Ivan 2011e, p. 26). Therefore, we selected the top 30 percent of predicted use areas and the associated habitat to represent the amount of potential lynx habitat in this unit. Our estimate of potential habitat (above) falls between the Ivan *et al.* (2011e, p. 26) estimate (about 18,700 km² [7,220 mi²]) and the USFS's habitat estimate (30,664 km² [11,839 mi²]; USFS 2008b, p. 18), while retaining a greater than 60 percent probability of detecting lynx as described by Ivan *et al.* (2011e, pp. 32-33).

We excluded the northwest part of the State, bounded on the south by US Interstate 70 and the east by Colorado State Highway 13, because this area lacks sufficient habitat to support lynx. Small areas of similar potential lynx habitat extend into south-central Wyoming and north-central New Mexico, and some lynx released in Colorado traveled into or through those areas. However, there is no evidence that either area supports resident lynx, and we doubt their ability to do so. This unit is not directly connected to lynx habitats and populations in Canada or to other DPS populations, although lynx dispersing from the north apparently arrived intermittently into the area historically, and long-distance dispersal (emigration) of translocated lynx from this unit to many western states and to Canada have been documented. The Southern Rockies are separated from the rest of the Rocky Mountain chain, and thus from lynx habitat in northwestern Wyoming and further north, by sagebrush and desert shrub communities in the Wyoming Basin and the Red Desert of southern and central Wyoming, and the arid Green and Colorado River plateaus of western Colorado and eastern Utah. Because of extreme topographic relief

juxtaposed with highways, residential communities, and other human developments, lynx biologists have identified habitat connectivity as an important consideration for the Southern Rockies (ILBT 2013, p. 54). Relative to other DPS lynx populations, this unit is about 400 km (250 mi) southeast of the GYA geographic unit.

Habitat Description - Lynx habitat in the Southern Rockies occurs within the subalpine and upper montane forest zones, generally above 2,900 m (9,514 ft) elevation (Shenk 2009, p. 10). In the upper elevations of the subalpine zone, forests are typically dominated by subalpine fir and Engelmann spruce. As the subalpine zone transitions to the lower-elevation upper montane zone, spruce-fir forests begin to give way to lodgepole pine and aspen. On cooler, mesic mid-elevation sites, Engelmann spruce may retain dominance, intermixed with aspen, lodgepole pine, and Douglas-fir. Lodgepole pine reaches its southern limits in the central part of the geographic unit, while southwestern white fir occurs only in the San Juan Mountains. The lower montane zone is dominated by ponderosa pine and Douglas-fir, with pines typically dominating on lower, drier, more exposed sites, and Douglas-fir occurring on the more sheltered sites. Lower montane forests do not support snowshoe hares and are seldom used by lynx except during dispersal and exploratory movements.

In this unit, lynx most commonly use mature Engelmann spruce-subalpine fir forests with total canopy cover of 42–65 percent and a conifer understory canopy of 15–20 percent, followed by mixed forests of Engelmann spruce-subalpine fir-aspen (Shenk 2008, p. 15; ILBT 2013, p. 52). Riparian and riparian-mix are the third most-used cover type, with a pattern of increasing use beginning in July, peaking in November, and dropping off in December. Large or medium willow-alder carrs and willow riparian communities provide important habitat for snowshoe hare, grouse, ptarmigan (winter), and other prey species (ILBT 2013, p. 52).

Habitat Status - Snowshoe hare (lynx foraging) habitat is naturally patchily-distributed in the Southern Rocky Mountains (ILBT 2013, p. 54), limiting hare abundance in this geographic unit. Dolbeer and Clark (1975, pp. 535, 539) estimated snowshoe hare density at 0.73 hares/ha (0.3 hares/ac) in Summit County in central Colorado, with the highest densities in mature and late-successional spruce-fir forests. However, this study was conducted in a very limited area and did not sample younger sapling-stage stands (15-40 years post-disturbance) to compare hare densities with those reported for mature and late-successional spruce-fir forests (USFWS 2008b, p. 32). Zahratka and Shenk (2008, pp. 910-911) estimated higher hare densities in mature Engelmann spruce-subalpine fir stands (0.08 to 1.32 hares/ha [0.03 to 0.5 hares/ac]) than in mature lodgepole pine stands (0.06 to 0.34 hares/ha [0.02 to 0.14 hares/ac]) in Taylor Park, Colorado. In contrast, Ivan *et al.* (2014, p. 587) estimated highest (summer) hare densities in early (20-25 years old) seral lodgepole stands (0.2 to 0.66 hares/ha [0.08 - 0.27 hares/ac]); intermediate densities in mature spruce-fir stands (0.01 to 0.26 hares/ha [0.004 - 0.1 hares/ac]); and lowest densities in mid-seral (40-60 years old) lodgepole stands that had been pre-commercially thinned (0.01 to 0.03 hares/ha [0.004 - 0.01 hares/ac]). Densities were more similar across the 3 forest types during the winter months; however, in all forest types and all seasons, hare densities were < 1.0 hares/ha (< 0.4 hares/ac) and in most cases were < 0.3 hares/ha (< 0.12 hares/ac; Ivan *et al.* 2014, p. 589). In fact, only 1 stand type (early seral

lodgepole) in 1 summer (2006) had an estimated density (0.66 ± 0.14 hares/ha [0.27 ± 0.06 hares/ac]) that exceeded the 0.5 hares/ha (0.2 hares/ac) threshold suggested as a minimum needed to support resident lynx over time (Ivan *et al.* 2014, p. 587, fig. 2). The information summarized above suggests that hare densities in this unit are low to marginal compared to units that have historically supported persistent resident lynx populations, and they may be inadequate to support long-term lynx persistence.

Colorado is currently experiencing historically unprecedented bark beetle epidemics in lodgepole pine and spruce-fir forests. By 2015, the spruce beetle outbreak influenced approximately 95 percent of the mature spruce component of the subalpine cover types on the Rio Grande National Forest (Squires *et al.* 2016, *unpubl. report*, p. 1), which contains most of the potential lynx habitat in the San Juan Mountains. Recent statewide sampling, however, indicates that snowshoe hare occupancy is invariant to time since beetle outbreak or severity of the outbreak (Ivan and Seglund 2016, pp. 2, 5), which suggests that the ongoing epidemic will not be catastrophic to lynx in Colorado. However, red squirrels are an important alternate food source in this unit, and occupancy of that species has declined markedly with the beetle epidemic (Ivan and Seglund 2016, pp. 2-3), which may be of some concern during periods when snowshoe hare abundance naturally fluctuates downward.

All USFS land management plans within the unit were amended by the SRLA in 2008 to provide for the conservation of lynx (USFS 2008a, entire; USFWS 2008b, entire). In 2008, the USFS reported that most LAUs on National Forest System lands in the Southern Rockies fell within a range of 3-8 percent in a currently unsuitable condition, with only 1 LAU exceeding the 30 percent unsuitable threshold established in the SRLA (USFS 2008b, p. 19). Currently, the USFS reports that 51 of 202 LAUs (25 percent) exceed the 30 percent unsuitable condition (McDonald 2016, *pers. comm.*). These changes are mostly in response to the ongoing bark beetle infestations and wildfires that have occurred since 2008. No forest management activities have resulted in LAUs exceeding the threshold.

Similarly, since the DPS was listed, all BLM Field Offices (FOs) in Colorado have been conserving lynx discretionarily through application of conservation measures provided in the LCAS (Ruediger *et al.* 2000, entire; ILBT 2013, entire). Three BLM FO plans in Colorado have been amended or revised to conserve lynx following the 2013 LCAS on lands totaling approximately 126 km² (49 mi²) of potential lynx habitat. One additional FO plan provides conservation measures for timber management actions only, but that FO administers only about 1 km² (0.39 mi²) of potential lynx habitat. To date, the remaining FOs have not formally amended or revised their plans specifically to provide conservation for lynx. Combined, these plans guide management of approximately 645 km² (298 mi²; about 2.6 percent of the geographic unit) of potential lynx habitat. Additionally, Rocky Mountain National Park has a fire management plan that includes conservation measures for lynx (Wrigley 2016, *pers. comm.*; Watry 2016, *pers. comm.*), although resident lynx have not been confirmed in the park. We are not aware of any specific lynx conservation strategies guiding activities on non-Federal lands in this geographic unit.

Lynx Status - The current number and distribution of resident lynx in Colorado are somewhat uncertain. However, experts suggest there may be 100-250 lynx in this unit, and we believe it is reasonable that lynx continue to occur in all national forests within the State. As of 2007, average annual survival among released lynx was 0.93 ± 0.03 within the study area in the San Juan Mountains and 0.82 ± 0.07 outside the study area boundary (Devineau *et al.* 2010, p. 5). Although 30 percent of known mortalities were due to human causes (being shot or hit by a vehicle; Devineau *et al.* 2010, p. 5), the estimate of survival within the study area was higher than those reported for natural, lightly trapped populations of lynx in the Yukon (0.75–0.90; Slough and Mowat 1996, entire; O'Donoghue *et al.* 1997, p. 155) or in the Northwest Territories (0.90; Poole 1994, p. 612). Successful reproduction, including by third- and fourth-generation offspring of translocated lynx, has been documented (Shenk 2008, p. 2); however, the average proportion of females that produced kittens (24 percent; Ivan *in* Lynx SSA Team 2016a, p. 22) and the kitten survival rate (0.23; Ivan 2016b, *pers. comm.*) were both lower in this geographic unit (during the period of intensive monitoring from 1999-2010) than rates reported for other geographic units where estimates were based on adequate sample sizes (Units 1 and 3; table 4).

The CPW has developed a minimally-invasive, long-term, state-wide monitoring program to track the distribution, stability, and persistence of lynx in Colorado (Ivan 2011e, entire) that may also eventually provide population trend information. As of 2016, this monitoring program detected evidence of recent lynx reproduction via camera captures of kittens accompanying adult females at 3 locations during the 2014-2015 and 2015-2016 monitoring efforts (Ivan *et al.* 2015, p. 1; Odell *et al.* 2016, p. 6). In addition, 38 percent of lynx captured during recent (2010-2015) RMRS research projects in Colorado have been young and/or unmarked cats (Ivan *in* Lynx SSA Team 2016a, p. 17), suggesting continued reproduction within Colorado. However, current reproductive rates are unknown. Finally, despite the large scale and almost complete mortality of the mature spruce component within the core release area of the San Juan Mountains, lynx continue to use and reproduce in the beetle-infested forests (Squires *et al.* 2016, *unpubl. report*, p. 2).

Factors Affecting Current Conditions

Regulatory mechanisms to conserve lynx habitats in Colorado are largely provided through Forest Service planning documents, as described above under Habitat Status. Because the majority (88 percent) of potential lynx habitat in Colorado is under Federal land management, actions occurring on other ownerships are unlikely to result in significant losses of lynx habitat within Colorado. However, habitat connectivity may be negatively affected by intense recreational use or development in key areas that are important for habitat connectivity, although this isn't a widespread phenomena or threat.

Although bark beetles are native insects and forests in the western United States have experienced regular insect infestations throughout their history, the current bark beetle epidemic is notable for its intensity and extensive geographic range. The causes of this epidemic include: relatively even-aged, dense, and homogenous forest conditions, which are highly susceptible to beetle attack, and which were created by large-scale logging in the late 1800s and subsequent

fire suppression efforts; warmer winters as a result of climate change (cold winters typically reduce beetle populations); and a multi-year drought that occurred in the mid-1990s through early 2000s, stressing the trees and making them more susceptible to beetle attack (USFS 2011b, p. 4).

In lodgepole pine forests, a mountain pine beetle epidemic typically kills the entire overstory and results in a stand-replacing disturbance event. In Colorado, more than 13,759 km² (5,312 mi²) have been affected by mountain pine beetle and 6,390 km² (2,467 mi²) have been affected by spruce beetle since 1996 (USFS 2015b, p. 3), a portion of which overlaps potential lynx habitat in this geographic unit. Even-aged mature and “dry” lodgepole pine stands characteristically have depauperate understory vegetation and are not capable of supporting dense populations of snowshoe hares. On moist sites, regeneration of beetle-killed lodgepole pine stands is expected to be relatively rapid (20-30 years), and the new stands will be dominated by a regenerating cohort of lodgepole pine or resprouting aspen. If these newly-established stands grow tall and dense enough to provide horizontal cover above the snow layer, they may produce excellent habitat for snowshoe hares and lynx for several decades, until the crowns again lift above the reach of snowshoe hares.

A spruce beetle epidemic kills the larger-diameter trees and can also result in a stand-replacing disturbance event. Because of the importance of spruce-fir forests for production and survival of snowshoe hares, widespread mortality of mature spruce-fir forests could impact lynx habitat for a long time.

ILBT (2013 p. 57; 61-62) states:

Plague, a flea-borne disease caused by the bacterium Yersinia pestis, which is not native to North America, was reported for the first time in lynx in Colorado (Wild et al. 2006). Pneumonic plague appeared to be the direct or indirect cause of death of 6 reintroduced lynx between 2000 and 2003. When translocated from Canada and Alaska, none of the lynx had antibody titers to Y. pestis; it appears likely that lynx were exposed to plague by infected prey after their release in Colorado.

Vehicular collisions are a potentially important cause of mortality for lynx in portions of the southern Rockies. Thirteen of 102 mortalities documented for lynx translocated into Colorado were from vehicle collisions (Devineau et al. 2010). Brocke et al. (1990) suggested that translocated animals might be more vulnerable to highway mortality than resident lynx and this could have been a factor in Colorado at the time of listing. Currently, the majority of lynx mortalities caused by vehicle collision (13 of 16) occurred during the reintroduction period (1999-2006). Since early 2007, one year after the final reintroductions occurred, only 3 hit by vehicle mortalities have been reported, and only two of those occurred in Colorado (Broderdorp unpublished data 2016). A number of highways with high speed and high traffic volume pass through lynx habitat, such as I-70, I-80, US 50, US 550 and US 160. These highways are not a barrier to lynx movement, as repeated successful crossings by radio-telemetered lynx have been

documented on I-70 and Highways 9, 40, 50, 91, and 114 (Ivan 2011b, c, 2012; J. Squires, personal communication 2012). At this time, it appears that hit by vehicle mortality may be a less significant mortality factor for lynx in Colorado.

As compared with other portions of the range of lynx, in Colorado more winter recreation and associated development overlaps with lynx habitat. Preliminary information from a study in Colorado indicates that some winter recreation uses may be compatible, but lynx may avoid some developed ski areas (J. Squires, personal communication 2012). It is possible that ski areas and 4-season resorts may reduce the amount and availability of lynx habitat within localized areas, in part by influencing the distribution or abundance of prey resources within the developed area. However, there is also considerable anecdotal evidence of lynx using ski areas.

Leg-hold trapping is currently prohibited under the state constitution of Colorado as a means of predator control or for commercial and recreational trapping. If a landowner can prove that all other non-lethal methods have been ineffective, a 30-day exemption may be granted for depredation cases. Incidental trapping mortality of lynx may be a minor risk during trapping seasons in southern Wyoming and surrounding states.

Predator control activities on federal lands, including coyote shooting or trapping, are common throughout most of this geographic area, mostly related to the grazing of domestic sheep. The majority of sheep grazing occurs on arid rangelands, but some grazing does occur during summer at the higher elevations, especially in south-central Colorado. Incidental capture of lynx is possible, but unlikely.

In summary, there are currently many more resident lynx in this unit than likely occurred historically, and many more than were known or suspected at the time the DPS was listed. There were even fewer verified records in this unit during the last century than in the GYA, and no reliable evidence of a resident breeding population. However, from 1999-2006, 218 Canadian and Alaskan lynx were released into the San Juan Mountains of southwestern Colorado. As a result of the subsequent reproduction of some of the released lynx and some of their offspring over several generations, resident lynx currently occupy this unit. When the DPS was listed in 2000, 27 of 41 radio-marked lynx released in 1999 were still alive. The State of Colorado has concluded that its efforts have established a viable lynx population, and the State's lynx experts suggest this unit may currently support 100-250 resident lynx (Ivan *in* Lynx SSA Team 2016a, p. 47). Recent (2010-2016) snow-tracking and camera surveys in the San Juan Mountains in the southern part of the unit documented evidence of continued lynx residency and reproduction.

Chapter 5: Future Conditions

In this chapter, we present our assessment of the future condition of the lynx DPS in terms of redundancy, representation, and resiliency. Given the uncertainty about the historical distribution of resident lynx in the contiguous United States and the current lack of reliable

estimates of the sizes, trends, and many demographic parameters for most DPS populations, it is difficult to confidently predict the future condition of the DPS or the likelihood that any given geographic unit will support resident lynx in the future. We lack data to build rigorous empirical population models for lynx across the DPS range, and uncertainty regarding the timing and magnitude of potential impacts to lynx from continued climate warming also limits our ability to predict the future condition of the DPS. Therefore, our assessment of the future condition of the DPS is based on our evaluation of the available scientific information regarding the factors identified by the ILBT as the most likely to have population-level impact to lynx in the DPS (ILBT 2013, pp. 68-78) and on the best professional judgments and opinions of lynx experts.

We provide brief summaries of the possible future conditions in each geographic unit, followed by a more detailed evaluation of the factors likely to influence lynx populations and habitats in each unit. We present and summarize the professional judgments and opinions of a panel of 10 lynx experts regarding the factors likely to influence the persistence of resident lynx populations in each of the 6 geographic units. We also present and summarize the experts' projections, based on consideration of those influencing factors, of the probability that each of the geographic units will continue to support resident breeding populations of lynx into the future (at years 2025, 2050, and 2100), and the sources of uncertainty that influenced their confidence in their predictions. Although we did not ask experts to evaluate different specific scenarios (e.g., climate models using different greenhouse gas emissions scenarios), we did ask them to provide the highest and lowest probabilities that each unit would continue to support resident lynx populations in the future, in addition to what they considered the "most likely" probability (see figs. 9-15, below).

Formal elicitation of expert opinion where empirical information is unavailable or inadequate is an appropriate and scientifically supported approach (Morgan 2014, entire). However, we remind readers that the output remains the experts' best professional judgment, which is subjective and, therefore, inherently different than experimentally collected data subjected to rigorous statistical analyses. For purposes of useful and meaningful presentation and comparison among geographic units, it was necessary to combine, quantify, graph, and summarize the qualitative information provided by experts. However, we caution that the results we present below and describe more fully in this chapter should not be interpreted as precise, statistically robust estimates of the probability that resident lynx will persist in the DPS or in any individual geographic unit in the future. Readers should consider the inherent limitations and substantial uncertainties in expert responses, particularly over longer time periods.

After summarizing experts' inputs, we then present our evaluation of the scientific literature regarding how certain anthropogenic factors may influence future conditions for resident lynx in each geographic unit. The factors we consider for each geographic unit include regulatory mechanisms (the factor for which the DPS was originally listed under the ESA) and the anthropogenic influences identified by the Interagency Lynx Biology Team (ILBT) as having the potential for population-level impacts to lynx in the DPS (climate change, vegetation management, wildland fire management, and habitat loss/fragmentation; ILBT 2013, pp. 68-78; see also chapter 3, above). Other factors were also evaluated for some geographic units if the

Core Team member most familiar with that unit felt those factors could pose meaningful, even if less likely, risks to the unit's continued ability to support resident lynx. After considering all of the above, we present our conclusions regarding the future conditions for resident lynx populations in each geographic unit and we discuss the extent to which our conclusions agree with or differ from the projections provided by the lynx expert panel we consulted and, if they differ, why.

Implicit in our evaluation of the future for lynx in the contiguous United States is our recognition and consideration of a possible future in which the DPS is not listed under the ESA. However, given (1) the history of lynx management, research, monitoring, and habitat conservation efforts by State wildlife and natural resource agencies in most states throughout the DPS range; (2) similar efforts by Federal land managers and related formal amendments or revisions to their land management plans to address the threat for which the DPS was listed (the inadequacy of previous regulatory mechanisms); (3) Tribal wildlife conservation efforts and philosophies; and (4) the DPS's listing and consultation history, we do not evaluate the unlikely hypothetical future in which all protections and conservation efforts would disappear if the DPS was not listed. Rather, although some protections could be relaxed (e.g., less stringent analyses of project-related impacts, potential for some states to reinstitute limited trapping harvest), we assume that Federal, State, and Tribal agencies and some private landowners would continue to manage for the conservation of resident lynx populations in those places that can support them in the DPS range. Our evaluation, therefore, considers the possibility of future relaxing of some lynx conservation measures and efforts, but not the complete absence of all protections for lynx. Some of the experts we consulted indicated that their projections assumed the status quo (i.e., continued protections under the ESA and current Federal and State land management policies). Others indicated their projections were not influenced by regulatory considerations but that doing so would not have altered their estimates; they felt that factors influencing lynx persistence on the landscape are independent of ESA listing status (Lynx SSA Team 2016a, p. 52).

As mentioned above, we do not define and evaluate specific and explicit climate change or greenhouse gas emissions scenarios or attempt to quantify differences in DPS viability or the persistence of resident lynx populations in individual geographic units based on differences in the rate and extent of potential impacts associated with projected continued climate warming. This is because of the limited resolution and inherent uncertainty of available climate models and the inadequacy of existing demographic data for projecting lynx population sizes and trends in the DPS over time, including their potential responses to a range of climate-mediated potential future habitat conditions. Therefore, this SSA does not constitute or include a formal climate change vulnerability assessment (Glick *et al.*, editors, 2011, entire) for the lynx DPS. Instead, underlying our evaluation in this SSA is the recognition that the lynx, as a broadly-distributed boreal forest-and snow-associated predator that relies heavily on a single, similarly-specialized prey species, and whose habitats are naturally influenced by climate-mediated disturbance factors (e.g., wildfire, forest insects, wind/ice storms, etc.), is likely highly sensitive and broadly exposed to the impacts of climate change and has limited adaptive capacity to respond to it. Therefore, we (along with the experts we consulted and the ILBT) consider lynx populations in the DPS vulnerable to the projected impacts of continued climate warming. While

we recognize that the pace and extent of impacts would be expected to differ under specific emissions or modeling scenarios, the limitations described above preclude us from quantifying those differences and their potential influence on the likelihood that resident lynx will persist in the DPS or in individual geographic units.

5.1 Summary of Future Conditions DPS-wide

Overall, our evaluation of the scientific literature and expert input suggests that resident lynx populations are likely to persist in each of the geographic units where they currently occur in the near-term (though year 2025), and in all or most of those units at mid-century (year 2050; see table 1, above, and figs. 9-15, below). Over the longer-term (out to year 2100 and beyond), populations in each of the geographic units and, therefore, in the DPS as a whole, are likely to be smaller and their distributions reduced. These anticipated declines are likely to be most influenced by projected loss and increasing fragmentation and isolation of boreal forests and favorable snow conditions resulting from continued climate warming and related impacts (e.g., increased wildfire and forest insect activity, diminished hare populations; Lynx SSA Team 2016a, p. 58). This outcome seems likely regardless of which climate emissions scenario is used to model future conditions, although the timing, extent, and magnitude of impacts is uncertain and would likely vary by scenario.

In addition to climate change, forest management also has the potential to influence (negatively or positively) hare and lynx habitats in the DPS range. Forest management on private lands that lack lynx conservation commitments may contribute to future declines in the amount and quality of lynx habitats, particularly in Maine and perhaps also in Minnesota (private lands contribute minimally to lynx habitats in the other geographic units – see table 2 in chapter 1). Uncertain future forest ownership and markets for forest products, shifts in silvicultural practices, and development pressures on private lands all may affect the resiliency of future lynx populations in these 2 units. Increased frequency, size, and intensity of wildfires and forest insect outbreaks, both driven by climate warming, are of concern for western geographic units.

Although all 5 geographic units that currently support resident populations (all units except the GYA) are, individually, expected by lynx experts (based on the median of experts' "most likely" persistence probabilities) to continue to do so at 2025 and through 2050, only 1 unit (Northwestern Montana/Northeastern Idaho; Unit 3) had an expert-estimated probability of persistence greater than 50 percent (i.e., persistence more likely than not) by the end of the century (see fig. 12, below). Expert input suggests that all other geographic units individually have a 50 percent or greater probability of functional extirpation (i.e., no longer capable of supporting resident lynx populations) by the end of the century, although all experts expressed substantial uncertainty regarding projections that far into the future (figs. 10, 11, and 13-15, below; also see Lynx SSA Team 2016a, pp. 36-49).

Cumulatively, expert responses suggest a high (about 80 percent) "most-likely" probability that resident lynx populations will persist in all 5 units that currently support them (all units except the GYA) in the near term (year 2025; see fig. 9, column 2; row 2, below). Expert responses

similarly suggest a high (80 percent) likelihood that at least 4 of the 5 units will continue to support resident lynx at mid-century, and a cumulative probability just under 50 percent that all 5 will do so (see fig. 9, column 2; row 3, below). Over the longer term, expert responses cumulatively suggest a high (about 85 percent) likelihood that at least 2 of the 5 units will support resident populations at the end of the century; a more than 50 percent likelihood that 3 units will do so; but also a high (> 75 percent) likelihood that resident lynx populations will be functionally extirpated from 2 of the 5 units that currently support them by the end of the century (see fig. 9, column 2, row 4, below; see Cummings, 2016, pp. 6-20 for details on the data and software used to generate figs. 9-15, below). The experts we consulted expect the likelihood that lynx populations will persist to decline in each geographic unit in the future, although uncertainty increases with time from the present, and increases greatly for end-of-century projections (Lynx SSA Team 2016a, pp. 36-49; also see 5.2).

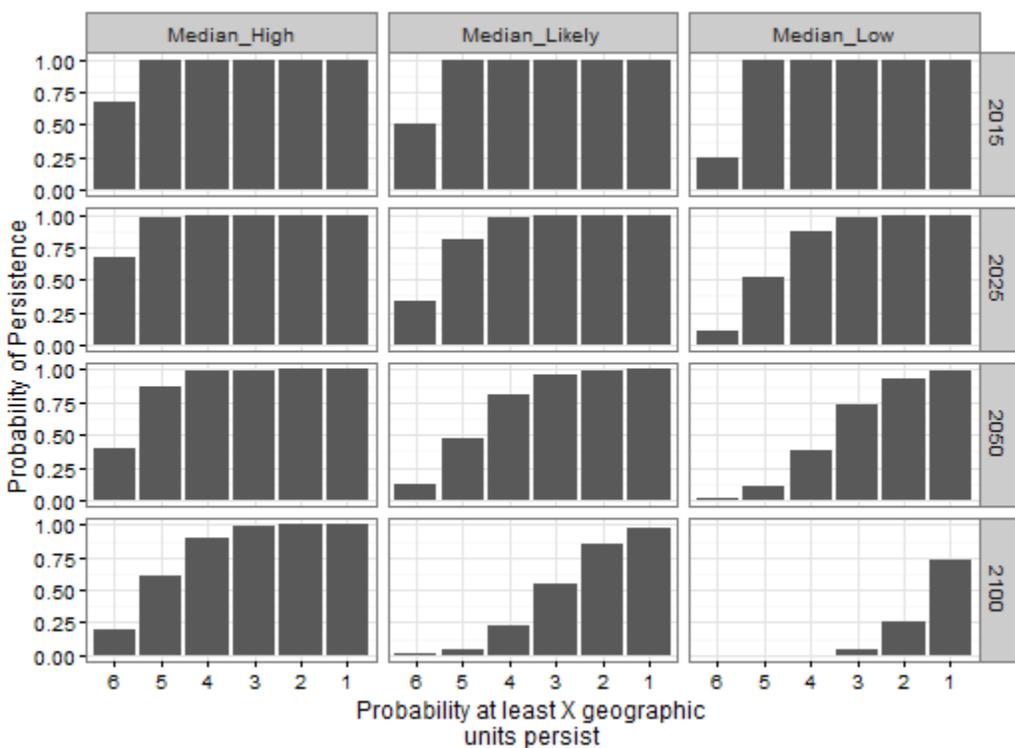


Figure 9. Summary of lynx experts' predictions regarding the probability of persistence of at least a given number of geographic units given the probability of persistence for each individual geographic unit. The y axis of each grid in figure 9 is the probability that at least the number of geographic units indicated by the x axis of the grid persist. The probability in a bar reaches 1 when there is no probability of fewer geographic units persisting. Moving from top to bottom, the grids show the probabilities by time period (2015 [current at time of expert elicitation], 2025, 2050, and 2100). Moving from left to right the grids show the range of expert responses by summary selection type and probability response. Therefore, looking down a column of grids provides a view of the trend in persistence through time and looking across a row of grids provides a view of the range of uncertainty in expert projections of persistence for a given time period.

Our evaluation generally concurs with the expert input we received. We believe that lynx populations and habitats in the DPS will decline over time largely as a result of continued climate warming and associated impacts, which are likely to exacerbate the potential adverse effects of other factors (e.g., forest management, potential increased competition from other hare predators). We acknowledge that under a “worse case” climate modeling scenario the boreal and subalpine forests and snow conditions associated with lynx occupancy could completely or largely disappear from some units (e.g., Minnesota; Galatowitsch *et al.* 2009, pp. 2015-2016) and be substantially reduced in the remainder before the end of the century. However, we are aware of no climate modeling that suggests the complete disappearance of potential lynx habitat from the entire contiguous United States by the end of the century. Complete loss of lynx habitat is perhaps more likely in the Northern Maine and Northeastern Minnesota units where there is little potential for elevational refugia compared to the more topographically diverse units (3 through 6) in the western United States. Under such a scenario, resident lynx would be unable to persist in some units and would be severely restricted in number and distribution in others, with any remaining resident populations more vulnerable to demographic and environmental stochasticity, genetic drift, and catastrophic events than they are currently.

Conversely, under a “better case” climate scenario (perhaps combined with a “better case” future forest management scenario), it is possible that resident lynx could continue to persist through the end of the century in all 5 geographic units that currently support them. Even under this scenario, however, we would expect smaller population sizes and reduced distributions in each unit resulting from the impacts of even moderate continued climate warming. We are aware of no models that predict climate cooling or climate-mediated improvement in lynx habitat conditions in the contiguous United States over the next century. We cannot quantify the likelihood of either of these extreme scenarios nor improve the accuracy or precision of, or our confidence in, the experts’ predictions regarding persistence.

Considering this range of potential future climate conditions, associated uncertainties, and expert input, we conclude that over the short-term (through year 2025), resident lynx populations are very likely to persist in all 5 geographic units that currently support them. We likewise conclude they are likely to persist in the mid-term (through 2050) in all or most geographic units that currently support them, with corresponding maintenance of redundancy and representation, despite reduced lynx numbers and distribution and, therefore, reduced resiliency among all or most populations. Recognizing the high level of uncertainty associated with predications beyond mid-century, we nonetheless conclude it is very unlikely that resident lynx populations will persist through 2100 in all 5 of the geographic units that currently support them. That is, we believe that resident populations will likely persist at the end of the century in 2 or 3 of the 5 units that currently support them, but that resident populations may be functionally extirpated from 2 to 3 of the units by then. Even where populations persist, they will be reduced in number and distribution and, therefore, resiliency.

The loss of viable resident lynx populations from 1 or more geographic units would represent reduced future redundancy, representation, and resiliency within the lynx DPS. With regard to

redundancy, however, our evaluation of the scientific literature and expert input indicates that no individual geographic unit that currently supports resident lynx is vulnerable to extirpation from a single catastrophic event. Given that, we conclude that the DPS as a whole is not vulnerable to extirpation from a catastrophic event (i.e., we find that there is a zero probability that a single catastrophic event could result in extirpation of resident lynx from any of the 5 geographic units that currently support them and, therefore, a zero probability of catastrophic extirpation of the entire DPS). As described above (section 1.3), we do not consider continued anthropogenic climate warming a catastrophic event; rather, we consider it a systemic, ongoing, and pervasive stressor, not a single temporally- and spatially-discrete event. We recognize that a sequence of discrete but spatially-clustered catastrophic events in lynx habitats over a short time could increase the potential for functional extirpation in 1 or more of the individual geographic units (especially the possibility of additional large wildfires in north-central Washington), thereby reducing redundancy within the DPS. However, as long as resident lynx remain geographically well-distributed in 1 or more units within the DPS, extirpation of the DPS from a single catastrophic event is very unlikely.

With regard to representation, although some lynx populations in the DPS units are demographically isolated from each other and the level of interaction between others is uncertain, there seems to be little risk of significant genetic drift. This is because of the currently observed and likely future high level of gene flow across most of the lynx's continental range, the species' well-documented dispersal capability, and the current and likely future connectivity and absence of significant barriers to dispersal between Canada and most DPS geographic units. Based on these factors and expert input, we find that there is no indication that the relatively low level of genetic diversity currently observed among lynx populations is likely to reduce DPS viability in the future (Lynx SSA Team 2016a, p. 51) and no indication that future gene flow is likely to be substantially reduced (79 FR 54793). This information suggests the current and likely future relative genetic health of the DPS. However, as noted in section 2.2, the potential for genetic drift among DPS populations would be expected to increase at some point in the future if lynx and hare habitats shift northward and upslope, as projected with continued climate warming, resulting in reduced connectivity and gene flow among smaller and more isolated lynx populations at the periphery of the range. This would result in (1) smaller and more distant potential source populations, reducing the likelihood and number of immigrant lynx reaching DPS populations, and (2) smaller effective population sizes among DPS populations, making them more vulnerable to drift, the consequences of which could include lower survival and reproduction rates and loss of adaptive potential.

How the potential loss of resident lynx from 1 or more geographic units may affect representation within the DPS in terms of ecological diversity is uncertain. Despite similarities in the fundamental components (vegetation, snow conditions, and hares) that define the ecological niche of lynx DPS-wide, differences in habitats and how lynx use them are apparent. For example, the amount of snow that seems to demarcate a boundary between lynx and bobcat occupancy in Maine (270 cm/yr [106 in/yr]) is almost twice that observed in Minnesota (140 cm/yr [55 in/yr]), and lynx in some parts of the West select mature forest stands, particularly in winter, while in other parts of the DPS, younger regenerating stands are most important. The

loss of resident lynx from any of the geographic units could result in the loss of behavioral and potential future genetic adaptations to the climate-mediated changes now occurring and likely to continue into the future at the southern edge of the lynx range. Such potential adaptability to diminished snow conditions, increasingly patchy and isolated boreal forests, and reduced hare abundance may be important to the taxon as a whole faced with a rapidly changing climate.

Because resident lynx populations in all geographic units that currently support them are expected to become smaller and more fragmented and isolated, each geographic unit and the DPS as a whole will be less resilient in the future. Our analyses and expert input suggest that resiliency will likely be sufficient to foster persistence of resident lynx in most units through mid-century but that its declining trajectory over time could result in extirpation of resident populations from 2 to 3 (of 5) units by the end of the century. Projected continued climate warming is expected to exert the greatest influence on the resiliency of individual populations, and thus continued presence of resident lynx in each geographic unit. Climate models project that boreal forests and snow conditions favorable for lynx at the southern periphery of the range will retreat northward and upslope with continued warming, further fragmenting and diminishing the quality of lynx and hare habitat within the DPS. Although uncertainty remains regarding the timing, extent, and biological consequences of such impacts, as habitat conditions decline, hare and lynx reproductive and survival rates are likely to decrease, resulting in population declines in both species. As snow conditions become less favorable, competitors (e.g., coyotes and bobcats) may outcompete and displace lynx. This in turn would reduce lynx abundance and density within populations, making populations more susceptible (i.e., less resilient) to stochastic events.

5.1.1 Summaries of Future Conditions in Each Geographic Unit

Unit 1 – Northern Maine: Although the Northern Maine geographic unit currently has extensive lynx habitat, the amount and distribution of high-quality habitat is projected to decline over the next 2 to 3 decades. Forestry practices, climate change, habitat loss and fragmentation, spruce budworm outbreaks, and development are most likely to drive future hare and lynx habitat in this unit. Lynx habitat and lynx densities are expected to decline by 50 to 60 percent by 2032 in response to aging of the budworm-era clearcuts and the effects of extensive partial harvesting since the 1989 passage of the Maine Forest Practices Act (Simons 2009, pp. 209, 217). In the next few decades, high-quality hare habitat is projected to decline from about 10 percent to 5 percent of the landscape (Simons-Legaard 2016, fig. 8, p. 10), perhaps more in line with likely historical conditions. High-quality habitat patches will likely become more fragmented, smaller, and more isolated, thus making the landscape less suitable for lynx than it currently is. For the next few decades the best habitat (young regenerating stands) will occur in the southern portion of current lynx distribution, where effects of climate change and potential competition with bobcats are likely to be greatest (Simons-Legaard *et al.* 2016, p. 1267). Absent long-term lynx management agreements, the future of lynx habitat in this unit is uncertain. Wood products markets will likely continue to change and could be affected by interest in carbon sequestration in response to climate change, with potential consequences for forest management in this unit. Recent rapid changes in private forest land ownership are likely to continue and could result in

subdivision of large ownerships. Non-forestry land uses (wind energy development, transmission line corridors, residential and resort development, and unmanaged conservation lands) may compete with forest management as the primary future land use. Conservation easements will limit development pressures in some areas and keep some lands as working forest, but forest practices (e.g., partial harvesting, northern hardwood management) may not create new lynx habitat or maintain the current historically high amount of high-quality habitat. Climate change is expected to affect this unit more than some others in the DPS because snow amount and duration already seem to be at thresholds for lynx and there are few potential elevational refugia. In the near term and beyond, snow quantity and quality will likely continue to deteriorate, which could cause lynx range to contract northward.

Our review of the published literature and input from lynx experts lead some members of the SSA Core Team to conclude that lynx could become extirpated from this unit before the end of the century. Climate change, increasing demand for hardwood forest products, a pending spruce budworm outbreak, and frequent forest disturbance all will likely contribute to the trend in the loss of spruce-fir forest and expansion of northern hardwoods, although the timeframe for conversion is uncertain. The lynx experts we consulted indicate the likelihood that resident lynx will persist in this unit will decline to about 50 percent by the end of the century, although there was wide variation and much uncertainty in opinions. After reviewing the scientific literature concerning climate change projections (diminishing snow conditions, lack of elevational refugia), some members of the Core Team were more pessimistic about the future of lynx in Maine than the lynx expert panel. In particular, we observed that there is great uncertainty about the future of forest management and future development on private forest lands. The lack of forest planning for lynx was not perceived or defined as a threat for this area when the DPS was listed. Nonetheless, forest management practices clearly have influenced that amount of high-quality lynx habitat and thus lynx numbers in this unit, and they are likely to continue to influence its population in the future. Currently, there are no long-term management plans in place on most privately-owned forest lands in this unit; State forest regulations have greatly influenced harvesting practices that have reduced landscape hare densities and will likely continue to do so; markets for forest products are depressed; and forest modeling projections (under current harvest scenarios) suggest that habitat will diminish and shift southward in the near term because of post-harvest succession and recede northward over the longer-term because of continued climate warming.

Unit 2 - Northeastern Minnesota: The direct and indirect effects of climate change are expected to affect lynx into the future in Minnesota. Specifically, boreal conifer forest is projected to contract northward, resulting in increased habitat loss and fragmentation and increased isolation of Minnesota lynx with diminishing forest conditions in southern Ontario. Additionally, the quantity, quality, and duration of snow are projected to decline; potentially resulting in increased competition and hybridization with bobcats as snow conditions favorable to lynx are diminished. The likelihood that resident lynx will persist in this unit is projected to decrease over time with increasing uncertainty through the end of the century, driven in the near term by decreasing quality, quantity and persistence of snow and over the long term from loss of spruce-fir forests. We expect the SNF will continue to implement lynx conservation measures in accordance with

its Forest Plan, thus continuing to minimize several risk factors and promote the conservation of lynx into the future. If the DPS is de-listed, the species would be placed on the Forest's Regional Forester Sensitive Species list for at least 5 years, which would give it a higher priority than other species for monitoring and management during that time. We also expect that MNFRC guidelines will remain in place into the future and that voluntary actions will continue on State and private lands. However, it is unclear on what proportion of State and private lands these voluntary actions will be implemented into the future. Further, these guidelines are generalized for listed species and give no specific direction for lynx. Taking these factors into consideration, median "most likely" probabilities of persistence generated by lynx experts were high for the near- and mid-term (> 95 percent at year 2025; 80 percent at year 2050), but declined to 35 percent (with great uncertainty) by 2100. We concur with the expert panel that resident lynx are likely to persist in this unit at 2025 and 2050. However, after reviewing the scientific literature concerning climate change projections (diminishing snow conditions, loss of boreal forest, lack of elevational refugia, and the potential for increased competition, disease, and insect outbreaks), some members of the SSA Core Team were slightly less optimistic about the long-term future of lynx in Minnesota than the lynx expert panel. The Core Team concluded that the climate-mediated conversion of boreal forest to temperate forest and the loss of favorable snow conditions could occur at a rate and extent that would result in a lower likelihood of persistence than projected by experts, including the possibility that resident lynx could be extirpated from this unit by the end of the century.

Unit 3 - Northwestern Montana/Northeastern Idaho: As in other units, climate change is projected to reduce the future amount, distribution, and quality of lynx habitat in this unit via northward and upslope contractions of favorable snow and forest vegetation conditions. This would result in increased fragmentation and isolation of habitats and smaller and more isolated lynx populations. Increased wildfire frequency and extent and perhaps other climate-mediated factors (forest insect outbreaks, changes in northern hare/lynx cycles that may influence immigration into this unit) could also reduce future lynx habitats and populations in this unit. Fire- and insect-related habitat losses would likely be temporary, resulting subsequently in improved habitat conditions when impacted areas regenerate the dense vegetative structure conducive to hare abundance. Continued forest management to conserve and maintain the vast majority of lynx habitats in this unit would benefit resident lynx in the future, though it is unlikely to offset the projected adverse consequences of continued climate warming. Lynx experts felt that future extirpation of lynx from this unit from reduced genetic health or a catastrophic event is unlikely. However, the extent to which the future demographic and genetic health of lynx populations in this unit may be influenced by immigration is unknown. Considering the factors above, lynx experts felt this geographic unit has the highest likelihood of continuing to support resident lynx into the future in the near term (year 2025; median probability of persistence > 0.95), at mid-century (median = 0.90), and end-of-century (median = 0.78), despite a declining probability of persistence and greater uncertainty with increasing time from present, as in all units. After reviewing the scientific literature and evaluating the factors that may influence lynx persistence in this unit, we concur with the experts' conclusion that this geographic unit is likely the most secure in the DPS. We conclude that it is very likely to continue to support resident lynx in the short term (through 2025) and through mid-century, although the number of lynx, the

amount and distribution of high-quality habitat, and landscape-level hare densities are all likely to decline by mid-century as a result of continued climate warming and associated impacts. We also agree that this unit is more likely than not to support some resident lynx at the end of this century, although at that time we expect lynx numbers and distribution would be substantially reduced from the current condition and would, therefore, be more vulnerable to demographic, environmental, and genetic stochasticity and to catastrophic events, resulting in reduced resiliency.

Unit 4 - North-central Washington: Over the past 25 years, wildfires have (perhaps temporarily) eliminated or reduced the quality of about a third of lynx habitat within the North Cascades, which has significantly affected the status of and current viability of the lynx population in this geographic unit. As elsewhere, continued climate warming is anticipated to reduce the future quality and distribution of lynx habitat in Washington, potentially further exacerbating the recent losses of lynx habitat from wildfires. Projected warming may increase wildfire frequency and severity, which may result in further losses of lynx habitat. Climate change is also expected to reduce the quantity and quality of snow, potentially resulting in permanent reductions in the quantity and distribution of lynx habitat in this unit. These potential climate-driven reductions of lynx habitat could isolate resident lynx within this unit and reduce connectivity with neighboring lynx populations in the other geographic units and Canada. Continued forest management on both Federal and State lands would benefit lynx populations in Washington but is unlikely to ameliorate the potential negative effects related to climate change. Considering the recent reduction in lynx habitat and the projected impacts of climate change, experts indicated persistence probabilities of 60 to 90 percent (median = 80 percent) over the near-term (year 2025), 30 to 80 percent (median = 70 percent) at mid-century, and less than 50 percent (median = 38 percent) by the end of the century for resident lynx in this geographic unit. After considering the best available scientific information and input from lynx experts, the Core Team is generally in agreement with experts regarding the likelihood of long-term persistence of Canada lynx in this geographic unit. We expect this unit will continue to support a small resident lynx population through mid-century but that its ability to do so beyond then is questionable, and that functional extirpation of lynx from this unit by the end of the century is more likely than not.

Unit 5 - Greater Yellowstone Area (GYA): As elsewhere, climate change is projected to reduce the future amount, distribution, and quality of lynx habitats in this unit via northward and upslope contractions of favorable snow and forest vegetation conditions. This would result in increased fragmentation and isolation of habitats and smaller and more isolated lynx populations. Because potential habitats in much of this unit already are naturally highly fragmented and perhaps only marginally capable of supporting resident lynx, and because it appears to have never supported more than a small number of residents, its ability to do so in the future is tenuous. Lynx experts felt that the small number of lynx this unit appears capable of supporting and its relative isolation from other lynx populations make it more vulnerable to genetic drift and extirpation from catastrophic events or demographic or environmental stochasticity. However, the extent to which the future demographic and genetic health of lynx populations in this unit may be influenced by immigration is unknown. Increased wildfire frequency and extent and perhaps other climate-mediated factors (forest insect outbreaks, changes in northern hare/lynx cycles

that may influence immigration into this unit) could also reduce future lynx habitat in this unit. Continued forest management to conserve and maintain the vast majority of lynx habitats in this unit would benefit resident lynx in the future, though it is unlikely to offset the projected adverse consequences of continued climate warming. Considering the factors above, lynx experts felt this geographic unit has the lowest likelihood of supporting resident lynx into the future in the near term (year 2025; median probability of persistence = 0.52), at mid-century (median = 0.35), and end-of-century (median = 0.15), with a declining likelihood of persistence and greater uncertainty with increasing time from present, as in all units. After reviewing the scientific literature and evaluating the factors that may influence lynx persistence in this unit, we concur with the experts' conclusion that this geographic unit is the least secure in the DPS. We find that conditions for lynx in this unit are naturally marginal, both its historical and current ability to support a persistent resident lynx population are questionable, and that continued climate warming and associated impacts are likely to further diminish its already limited ability to support resident lynx. We conclude, based on the protected status (national park, designated wilderness, and non-developmental land use allocations) of vast areas and climate models that project some areas of adequate vegetation and snow conditions through the end of the century, that this unit may continue to occasionally or intermittently support a small number of resident lynx and some reproduction throughout the remainder of the century. However, we conclude that it is very unlikely to support a persistent resident population over the short-term (through 2025), even less likely that it will do so at mid-century, and it is highly improbable that this geographic unit will support resident lynx by the end-of-century.

Unit 6 - Western Colorado: Regulatory mechanisms that provide for the conservation of lynx in Colorado consist of State regulations prohibiting unauthorized take of lynx and amendments of USFS and BLM management plans, which limit vegetation management (among other things) covering approximately 85-90 percent of the lynx habitat within this geographic unit and provide guidance to limit habitat fragmentation. Climate change is expected to negatively affect vegetation and influence snow conditions in this unit. The elevation gradient in Colorado may provide refugia from deteriorating snow conditions in the future. Assuming that snow levels will increase in elevation, lynx habitat is likely to become more fragmented by areas that no longer retain appropriate snow conditions and vegetation. However, we anticipate large areas of snow persistence to remain through the end of the century. Wildland fire will likely result in temporarily reduced habitat quality to some extent; however, affected areas are likely to regenerate and provide excellent habitat conditions to support hares and lynx. Given projected climate warming, some areas that currently support snowshoe hare populations may experience vegetation type conversion that may not support snowshoe hares in the future. Considering the factors above, lynx experts felt this geographic unit has a high likelihood of continuing to support resident lynx into the future in the near term (year 2025; median probability of persistence = 0.90) and at mid-century (median = 0.80), and a reasonable likelihood of doing so at end-of-century (median = 0.50), despite a declining probability of persistence and greater uncertainty with increasing time from present, as in all units. This unit would be expected to continue to support resident lynx in the future if survival and reproductive rates similar to those estimated during intensive monitoring are maintained over the long-term. However, given the lack of evidence of historical occupancy by resident populations, the naturally limited and fragmented potential habitat,

generally low hare densities, low proportions of females that produce kittens, and low kitten survival rate, along with projected impacts of climate warming on all or most of these parameters, we are less optimistic than the lynx expert panel regarding the likelihood that this unit will continue to support resident lynx over the long-term.

Table 5, below, summarizes expert predictions of future lynx persistence and Core Team summary of factors thought likely to influence the future resiliency of lynx populations in each geographic unit.

Table 5. Expert-predicted future (2025, 2050, and 2100) persistence¹ of resident lynx populations in individual geographic units of the Canada lynx DPS and supporting evidence and uncertainties.

Geographic Unit	Median lynx expert probability of persistence (%) ² (range [%]) ³ at years 2025, 2050, and 2100	Key evidence	Uncertainties
Unit 1	<p><u>2025</u>: 96 (80-100)</p> <p><u>2050</u>: 80 (65-95)</p> <p><u>2100</u>: 50 (40-80)</p>	<ul style="list-style-type: none"> • 50% decline from current habitat projected by 2032; habitat shift to the south edge of current range • Slight recovery of habitat by end of century depending on forestry trends • Continued demographic and genetic connectivity to southern Quebec, New Brunswick populations • Climate models predict deteriorating snow quality, depth and duration; more severe than other units • Little potential elevation refugia 	<ul style="list-style-type: none"> • Future forest management trends and habitat conditions on private forest lands in Maine and Canada • Future shifts in land ownership, forest products markets, and development • Extent and pace of deteriorating snow conditions • Response of hares (pelage mismatch), bobcat, and fisher to changing snow regime • Extent and pace of spruce-fir loss • Future hare population trends • Disease and parasites in lynx • Effects of lynx trapping in Quebec
Unit 2	<p><u>2025</u>: 96 (88-100)</p> <p><u>2050</u>: 80 (60-90)</p> <p><u>2100</u>: 35 (10-60)</p>	<ul style="list-style-type: none"> • Smaller population could be susceptible to stochastic effects • Habitat conditions on SNF will remain stable or improve if managed for softwoods • Continued demographic and genetic connectivity to southern Ontario populations • Climate models predict deteriorating snow quality, depth and duration; loss of boreal forest • Little elevation gradient: lake-effect snow may retain refugia to 2050 but not 2100 	<ul style="list-style-type: none"> • Future forest management trends and habitat conditions on private forest lands in Minnesota and Ontario • Extent and pace of deteriorating snow conditions • Adequacy of immigration from southwest Ontario • Response of bobcat and fisher to changing snow regime • Rate of spruce-fir decline • Future hare population trends • Disease and parasites in lynx • Effect of lynx-bobcat hybridization
Unit 3	<p><u>2025</u>: 98 (95-100)</p> <p><u>2050</u>: 90 (70-100)</p> <p><u>2100</u>: 78 (50-90)</p>	<ul style="list-style-type: none"> • Some habitat loss from increased wildfire, otherwise habitat should remain stable with USFS/BLM management • Continued demographic and genetic connectivity to southern Alberta and BC populations • Potential elevational refugia • Recent loss of small sub-population in 	<ul style="list-style-type: none"> • Extent and frequency of fire in hare-lynx habitat • Extent and frequency of insect outbreaks • Extent and pace of deteriorating snow conditions • Adequacy of immigration from southern Alberta and BC

		<p>Garnet Range</p> <ul style="list-style-type: none"> Increasing fire frequency 	<ul style="list-style-type: none"> Response of bobcat, cougar, coyote to changing snow regime Extent and pace of elevational migration of spruce-fir Mismatch in elevation between appropriate snow regime for lynx and spruce-fir Future hare population trends
Unit 4	<p><u>2025</u>: 80 (60-95)</p> <p><u>2050</u>: 70 (30-80)</p> <p><u>2100</u>: 38 (5-50)</p>	<ul style="list-style-type: none"> Habitat and population low because of recent fires; could be susceptible to stochastic effects Continued demographic and genetic connectivity to southern British Columbia populations Elevation is not sufficient to provide long-term refugia from deteriorating snow quality, depth, and duration State uplisted from T to E (2016) 	<ul style="list-style-type: none"> Extent and frequency of fire in hare-lynx habitat Extent and frequency of insect outbreaks Extent and pace of deteriorating snow conditions Adequacy of immigration from southern BC Response of bobcat, cougar, coyote to changing snow regime Extent and pace of elevational migration of spruce-fir Future hare population trends
Unit 5	<p><u>2025</u>: 52 (10-70)</p> <p><u>2050</u>: 35 (15-60)</p> <p><u>2100</u>: 15 (5-50)</p>	<ul style="list-style-type: none"> Very low hare densities in much of unit Habitat should remain stable with USFS, BLM, and NPS management No direct connectivity with Canada populations; little immigration from DPS populations Potential elevational refugia Smaller population could be susceptible to stochastic effects 	<ul style="list-style-type: none"> Persistent vs. ephemeral historical presence Adequacy of immigration Extent and frequency of fire and insect outbreaks Extent and pace of deteriorating snow conditions Response of bobcat, cougar, coyote to changing snow regime Extent and pace of elevational migration of spruce-fir Future hare population trends Extent to which high elevation may provide climate and snow refugia
Unit 6	<p><u>2025</u>: 90 (60-100)</p> <p><u>2050</u>: 80 (50-85)</p> <p><u>2100</u>: 50 (20-70)</p>	<ul style="list-style-type: none"> Habitat loss from increased wildfire and insect outbreaks, otherwise habitat will remain stable with USFS management Isolation from other lynx populations Elevation may provide refugia from deteriorating snow quality, depth and duration Uncertainty about stability of recently-introduced lynx population 	<ul style="list-style-type: none"> Persistent vs. ephemeral historical presence Demographic and genetic effects of isolated population Extent and frequency of fire and insect outbreaks Extent and pace of deteriorating snow conditions Response of bobcat, cougar, coyote to changing snow regime Extent and pace of elevational migration of spruce-fir Mismatch in elevation between appropriate snow regime for lynx and spruce-fir Future hare population trends

¹We asked 10 recognized lynx experts to provide their estimates of the probability that resident lynx populations or subpopulations would persist in each geographic unit, even if reductions in lynx numbers and distributions were anticipated (i.e., the probability that resident lynx would *not* be functionally extirpated from the unit).

²Median “most likely” probabilities of persistence provided by 10 lynx experts for each geographic unit considering the current status of lynx populations and current and likely future stressors to those populations.

³The full range of “most likely” probabilities of persistence provided by the 10 lynx experts.

5.2 Future Conditions - Detailed Descriptions by Geographic Unit

In this section, we present and summarize the formally-elicited opinions of a panel of 10 lynx experts regarding the likelihood that each geographic unit will continue to support resident breeding lynx populations into the future (at years 2025, 2050, and 2100), the factors they think will influence lynx persistence, and the sources of uncertainty that influenced their confidence in their predictions. We then present our evaluation of factors that may influence future conditions for resident lynx in each geographic unit, our conclusions regarding future conditions in each geographic unit, and whether our conclusions concur with or differ from projections provided by the lynx expert panel we consulted.

As mentioned above, we remind readers that the text and figures presented here are intended to convey and summarize expert opinions, which are subjective. The graphs we provide are intended to illustrate individual and cumulative expert opinion and uncertainty, and to allow comparisons of projections of possible future lynx persistence among all geographic units. We do not imply, and readers should not infer, that these depictions represent statistically robust, accurate, or precise estimates of the actual likelihood that resident lynx will persist in the DPS or in any individual geographic unit in the future, and readers should consider the inherent limitations and substantial uncertainties in expert responses, particularly over longer time periods. In figures 10-15 below, responses for each lynx expert for each of the 3 probability-of-persistence levels, (i.e., highest, most likely, and lowest probabilities) are represented by the hollow red, filled green, and hollow blue points, respectively. The black X mark is the median of the most likely responses across the experts in each response year. The red, green, and blue dashed lines connect the median of the highest, most likely, and lowest probability-of-persistence responses across the experts in each response year. The edges of the gray areas were defined by the entire range of expert responses, from the largest of the highest-probability responses to the smallest of the lowest-probability responses. The median lines and gray areas are provided as a summarizing visualization to aid comprehension of the experts’ responses and their range, and should not be viewed as a substitute for individual responses or presented outside the context of the accompanying discussion. The gray area between red and blue dashed lines can be viewed as the median uncertainty across all 10 experts.

5.2.1 Unit 1 - Northern Maine

Expert Projections of Lynx Persistence

All of the experts that we consulted indicated an initially high and subsequently declining likelihood that resident lynx will persist in Maine through the end of the century, with uncertainty (range between lowest and highest estimates) also increasing over time (Lynx SSA Team

2016a, pp. 33-36). Climate change was an overriding near- and long-term stressor for lynx expressed by lynx experts.

Increased winter precipitation in the form of rain, reduced snow depth, and reduced snow durations were discussed by the experts. Experts believed that the effects of climate change would continue to increase as a stressor that would reduce lynx populations by mid- to end-of-century. Snow conditions would continue to deteriorate, potentially resulting in increased competition with bobcats and increased predation by fisher. We heard varying prognoses from experts regarding the speed at which climate-induced loss of spruce-fir forest may occur. The scientific literature suggests that loss of spruce-fir could occur relatively quickly in the Northeast, and several experts noted that an increase in northern hardwood composition of the forest is already occurring. One expert provided information that suggests that balsam fir could actually increase in the short-term (over the next few decades), but that the long-term prognosis is not favorable for natural spruce-fir regeneration. Decline or loss of spruce-fir could be accelerated by forest disturbance (e.g., budworm outbreaks or forest management affecting large acreages of lynx habitat annually).

In addition to climate change, lynx experts expressed a number of near-term stressors related to forest management in northern Maine. Land management objectives were uncertain because of frequent changes in private forest land ownership. Experts acknowledged uncertainty concerning the severity of and response by new landowners to future spruce budworm outbreaks. Experts believed that investment landowners are unlikely to respond to future budworm outbreaks as they did in the 1970s-80s (extensive clearcuts, herbicide application). Experts also acknowledged concerns about the effects of the aging of past clearcuts beyond conditions that support high-quality hare and lynx habitat.

Although uncertainty increases with time from the present, experts generally agreed that climate-related loss of favorable snow conditions (amount, consistency, and duration), loss of spruce-fir forest, and potential competition from bobcats would be expected to reduce the likelihood that lynx will persist in this unit. Experts also were uncertain about whether hare numbers would rebound to past higher levels or remain at current lower levels.

Taking all of these factors into consideration, experts provided “most likely” persistence probabilities of 80 to 100 percent (median = 96 percent) in the near-term (year 2025), 65 to 95 percent (median = 80 percent) at mid-century, and 40 to 80 percent (median = 50 percent) at the end of the century (fig. 10). As they did for most other geographic units, all experts indicated an initially high and subsequently decreasing likelihood that resident lynx will persist in this unit, with uncertainty increasing substantially over time.

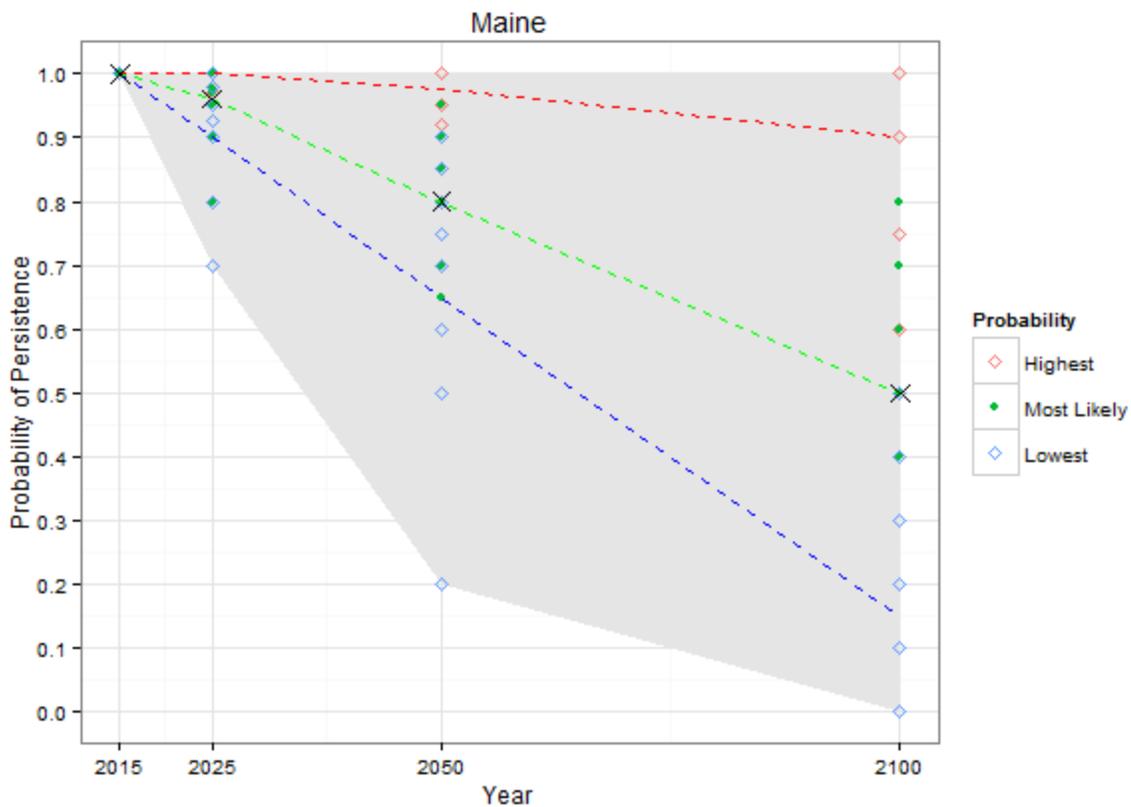


Figure 10. Lynx expert estimates of the probability that the Northern Maine Geographic Unit will continue to support resident lynx in the future (at years 2025, 2050, and 2100).

Service Evaluation of Factors Potentially Influencing Future Conditions

Regulatory Mechanisms - As described above (section 4.2.1), past forest management practices (large-scale clearcutting) have created an unnaturally high amount of high-quality hare habitat in this unit, resulting in a resident lynx population that is probably larger than typically occurred historically under natural conditions. Also as described above, a shift in forest management from clearcutting to various forms of partial harvesting that began in 1989 with passage of the Maine Forest Practices Act (MFPA) is unlikely to maintain or recreate this extensive high-quality habitat. Therefore, we expect lynx habitat and numbers to decline in this unit over the next several decades, perhaps to levels more consistent with likely historical conditions.

If timber harvest continues using methods and at rates similar to those that have predominated since passage of the MFPA (see section 4.2.1), lynx habitat at year 2030 is modeled to decline by about 50 percent from current anthropogenically influenced high levels (Simons-Legaard 2016, pp. 9-10). Habitat modeling indicates that the maturation of previously clearcut areas will result in a decline in high-quality hare habitat (i.e., lynx foraging habitat) in this unit from 7-12 percent of the landscape in 2010, to about 3-8 percent by year 2030, then increasing to 5-16

percent by 2060 (Simons-Legaard 2016, p. 10, fig. 8). After 2030, however, projected outcomes for lynx habitat become more uncertain and depend on assumptions about habitat definitions and harvest rates. Lynx in Maine selected for regenerating, conifer-dominated forest (> 75 percent conifer; Vashon *et al.* 2008b, pp. 1490, 1492-1494). If one defines high-quality lynx habitat as stands having greater than 75 percent spruce-fir, then such habitat will decline by about 50 percent by 2030 and then stabilize or increase slightly through 2060 (Simons-Legaard 2016, pp. 9,16; fig. 8).

The projections above do not consider a nearly 60 percent decline in snowshoe hare densities that has occurred in Maine from a period of high hare density in 2001-2006 (1.8 - 2.2 hares/ha [0.7 – 0.9 hares/ac] in regenerating conifer) to a period of lower hare density in 2008-2015 (0.8 – 1.0 hares/ha [0.3 – 0.4 hares/ac]; Harrison *et al.* 2016, entire). This decline occurred across all forest stand types and across a broad geographic area of Maine (Scott 2009, p. 36; Harrison *et al.* 2016, entire), and a decline in hare density also occurred in the adjacent Gaspé region of southern Quebec (Assells *et al.* 2007 *in* Scott 2009, p. 41-42). Hares remained at these lower densities through 2015 (Harrison *et al.* 2016, p. 55). If future hare populations remain low, then Maine habitats will likely have a lower capacity for supporting resident lynx. How current and likely future hare densities in this unit compare to densities under historical disturbance patterns is unknown.

The habitat projections above also do not consider the effects of future spruce budworm outbreaks. After low levels of infestation for the last 20 years, Maine appears poised for another spruce budworm outbreak. Budworm numbers are increasing toward epidemic levels in southern Quebec and northern New Brunswick. Significant defoliation could occur in Maine in the next few years, and the outbreak may last about a decade (Wagner *et al.* 2015; pp. 12-16). Although research has clearly demonstrated that landowner response to the last outbreak resulted in unintended benefits for lynx from 1 to 3 decades later, our ability to project what effects the next outbreak will have on lynx habitat is limited because land ownership has changed since the last outbreak. To reduce risk from spruce budworm, some financial investment owners may cut younger spruce-fir stands that still support elevated hare densities. Some may be less inclined to intensively manage for spruce-fir and may switch to an emphasis on northern hardwoods. It is unlikely that current landowners will broadly apply pesticides to control spruce budworm or herbicides to promote spruce-fir regeneration after stands are defoliated. The MFPA may constrain clearcutting of infested stands, even with recently-enacted changes intended to reduce the regulatory burden for landowners. Despite these uncertainties, landowner response to the pending budworm outbreak will likely have important implications for the short- and long-term persistence of lynx habitat in northern Maine (Simons-Legaard 2016, pp. 16-17).

Climate Change – Because this geographic unit generally lacks potential elevational refugia (Carroll 2007, p. 1102; Siren *in* Lynx SSA Team 2016a, pp. 15 and experts, p. 37), its lynx population may be more vulnerable to deteriorating snow conditions than populations in the more topographically diverse western units, and changes in snow conditions could further restrict lynx distribution (Hoving 2001, pp. 27-28; Hoving *et al.* 2005, p. 749; Carroll 2007,

entire). This unit's only potential elevational refugia under reduced snow scenarios are in the mountains of western Maine, where favorable snow conditions may only persist as very small, isolated "sky islands" that would be unlikely to support lynx. Carroll (2007, entire) modeled the Maine lynx population assuming non-cycling hare populations and snow conditions expected under intermediate to high emissions climate models (Kiehl and Gent 2004, entire). He predicted a 59 percent decline in the lynx population (the non-cycling hare population model) by mid-century because of climate change alone, with larger declines projected from interactions between climate change and other factors (potential increased trapping in Canada and lynx population cycling; Carroll 2007, p. 1100). Wildlife experts in Maine ranked lynx as highly vulnerable to climate change (> 66 percent loss in species range/population and extirpation within 50 to 100 years; Whitman *et al.* 2013, pp. 19, 74).

Climate change is already affecting the Northeast, and the rate of change is faster than expected, with large changes observed since 1970 (Rustad *et al.* 2012 p. 6). Rapid winter warming in recent decades is believed to be exacerbated by an albedo feedback caused by the diminished persistence of snow in winter (Hayhoe *et al.* 2006, p. 25). Average winter temperatures are increasing about 0.4°C/decade (0.8°F/decade) with the greatest warming occurring in the coldest winter months (January-February; Burakowski *et al.* 2008, p. 1). Northeast climate models predict average winter temperature increases of 2.0°C (3.6°F; low emission) to 2.9°C (5.2°F; high emission) by mid-century and 3.1°C (5.6°F; low emissions) to 5.3°C (9.5°F; high emissions) by late century (Notaro *et al.* 2014, p. 6529). The largest increases in temperature are expected in northern Maine (Siren *in* Lynx SSA Team 2016a, Appendix 3; Rawlins *et al.* 2012, p. 9) where temperatures may increase 2.5° to 2.8°C (4.5° to 5.0°F) by 2050 (Fernandez *et al.* 2015, p. 3). In response to climate change, interest in wind development has grown in northern and western Maine, which has the potential to impact high-elevation habitats and potential spruce-fir refugia (Publicover 2013, p. 2).

Gonzalez *et al.* (2007, pp. 12-13 and 15-18) modeled distribution of boreal forest and future snow conditions under 9 different low, medium, and high emission scenarios and predicted reduced probability of suitable snow (from 95 percent during 1961-1990, to 90 percent predicted for 2071-2100) and very minor changes in forest cover type in Maine by the end of the century. Although there are uncertainties about future climate warming, if projections are accurate, the area capable of supporting resident lynx in Maine could be expected to recede northward and lynx populations to decline substantially in this unit over the next 100 years (Vashon *et al.* (2012, p. 60). If future trends in increasing temperature and decreasing snow occur as projected, then at some time in the future lynx would be unlikely to persist in Maine.

Snow Duration - The current average snow duration in Maine is at or below the 4-month snow persistence threshold believed necessary to support lynx (section 4.2.1; Gonzalez *et al.* 2007, p. 7). Snow duration declined by 16 days in the Northeast from 1970 to 2001 (Wake 2005, p. 15) and is expected to diminish by another 2 weeks in Maine by mid-century (Fernandez *et al.* 2015, p. 10). It is projected to decline by 25 percent (low emissions) to 50 percent (high emissions) from current conditions by the end of the century (Hayhoe *et al.* 2006, pp. 21-25). Similarly,

Notaro *et al.* (2014, p. 6543) projected an average decrease of 28 days (low emission) to 47 days of snow cover (high emissions) by the end of the century.

Snow Depth - The current average annual snowfall in northern Maine is at or below the 270-cm/yr. (106-in/yr) threshold below which lynx are unlikely to occur (Hoving *et al.* 2005, p. 749; section 4.2.1), and it is expected to decline in the future with projected continued climate warming. From 1965-2005, Northeast winter snowfall has decreased by about 4.6 cm/decade (1.8 in/decade), with the greatest decreases occurring in December and February (Burakowski *et al.* 2008, p. 1). By the end of the century, large areas of the Northeast will experience 15-percent (under a low-emissions scenario) to 25-percent (high-emissions scenario) reductions in snowfall (Ning and Bradley 2015, p. 6). Similarly, Notaro *et al.* (2014, p. 6529) concluded that average snowfall in the northeastern United States and southeastern Canada will decline by 59 cm (23 in; 31 percent) under a low-emissions scenario) to 92 cm (36 in; 48 percent) under a high-emissions scenario by the end of the century because a higher proportion of winter precipitation is projected to fall as rain rather than snow. Hayhoe *et al.* 2006, (pp. 22-25) predicted that under moderate and high climate scenarios there would be large reductions in the length of the snow season with < 25-50 percent reductions in the number of snow days by 2070-2099.

Snow Quality - Winter precipitation in Maine is projected to increase by 10 to 15 percent by the end of the century (Hayhoe *et al.* 2006, p. 28) with a greater proportion of winter precipitation falling as rain (Huntington *et al.* 2004, entire; Hayhoe *et al.* 2006, p. 23; Ning and Bradley 2015, entire). Snow density and compaction (caused by wet, heavy snow or rain on snow events in winter) will likely continue to increase in the region in the future (Karl *et al.* 1993, entire; Dudley and Hodgkins 2002, pp. 8-10, 19-20; Huntington *et al.* 2004, p. 2632; Huntington 2005, entire; Hodgkins and Dudley 2006, entire).

Loss of Boreal Forest - The boreal spruce-fir forest type has come and gone from New England during the post-glacial period. It nearly disappeared from the Northeast during the interglacial warming period 1000 years ago, then moved south into New England only in the past few centuries during the "Little Ice Age" (Schauffler and Jacobson 2002, entire; DeHayes *et al.* 2000, entire). Continued anthropogenic climate warming is projected to cause another northward contraction of spruce-fir forest in the Northeast with potential negative consequences for both lynx and snowshoe hares (Gonzalez *et al.* 2007, entire). Because of its sensitivity to climate and its mobile nature, the spruce-fir forest type in the Northeast, including northern Maine, is projected to decline substantially in response to climate change even under low-emissions scenarios and could disappear completely under higher-emissions scenarios (Iverson and Prasad 2001, pp. 192-193; Prasad *et al.* 2007, entire; Beckage *et al.* 2008, entire; Iverson *et al.* 2008, p. 403; Ollinger *et al.* 2008, p. 17; Jacobson *et al.* 2009, p. 27; Tang and Beckage 2010, entire; Whitman *et al.* 2010, p. 12; Andrews 2016, p. 20). Even under the lowest emissions scenarios, spruce-fir forest would be reduced by the end of the century (Williams and Liebhold 1997, pp. 210-214; Prasad *et al.* 2007, entire; Mohan *et al.* 2009, pp. 221-222), although some spruce-fir may persist at the highest elevations (Tang and Beckage 2010, pp. 148-156) and along the eastern coast (Jacobson *et al.* 2009, pp. 26-29) where cooler conditions

would likely persist. Climate change is anticipated to increasingly fragment the boreal forest in northern New England (Iverson *et al.* 2008, pp. 400-405), which would diminish the amount and quality of lynx habitat (Simons 2009, pp. 221-222). Recent shifts of northern hardwoods to higher elevations formerly occupied by boreal forests have also been attributed to regional warming over the last century (Beckage *et al.* 2008, entire).

Spruce (red, black, and white) and balsam fir are the most important boreal forest conifer tree species in the Northeast and will be affected by climate change in different ways. Mechanisms of injury to spruce-fir include winter injury from freeze-thaw cycles, spring drought (because of reduced snowpack), and reduced seed germination (Auclair *et al.* 2010, pp. 694-695). Thus, the range of spruce-fir is limited by summer heat and drought. Mohan *et al.* (2009) projected that the suitable area for balsam fir would be 80 percent lower by 2100 under an average- to high-emissions scenario. In contrast, Ollinger *et al.* (2008, p. 8) projected increasing growth rates for balsam fir and red spruce to mid-century, after which they would decline. Andrews 2016 (p. 53, 104) modeled future climate envelopes for spruce and fir species in Maine under a moderate emissions scenario and predicted northward shifts in these species. The results suggest that areas of suitable climate for these tree species would diminish in northern New England by 2030, white and black spruce would disappear from northern Maine by 2060, and balsam fir and red spruce would dwindle to only a few high altitude locations by 2060. However, suitable habitat for spruce and fir species would remain in northern and coastal highlands of New Brunswick and Cape Breton Island Nova Scotia.

The timescale of the spruce-fir decline in the Northeast is difficult to predict because of the many variables that influence shifting of the forest species composition (emissions scenarios, the long lifespan and slow dispersal rates of trees, frequency of disturbance, competition from advancing hardwoods and invasive tree species, complex interactions with moisture, and synergistic effects with other pollutants). Support for an accelerated decline includes evidence that spruce-fir is already in decline and is being replaced in Maine by northern hardwoods (oak, pine, red maple). Since 1995, the area of forest land classified as the northern hardwoods type in Maine has increased 8.9 percent (by about 2,400 km² [927 mi²]) and the area in the spruce-fir forest type group has decreased 8.5 percent (1,987 km² [767 mi²]; McCaskill *et al.* 2016, p. 2). Although forest disturbance often favors northern hardwoods, it may, in some situations, favor balsam fir and help it persist longer in a warming climate (Scheller and Mladenoff 2005, p. 318). A pending spruce budworm outbreak and frequent disturbance from forest management could accelerate conversion to northern hardwoods. Other climate-related forest disturbances (forest pests, diseases) could further accelerate conversion to northern hardwoods (Iverson *et al.* 2008, p. 404).

In contrast, some authors note that trees migrate slowly in response to a changing climate and are long-lived. Therefore, a time lag may occur in shifting forest composition from spruce-fir to northern hardwoods (Mohan *et al.* 2009, p. 221; Zhu *et al.* 2012, pp. 1048-1051). Some northern Maine industrial forest landowners could “adapt” to climate change by intentionally favoring spruce-fir (e.g., by plantations and use of herbicides).

Finally, there is uncertainty concerning the influence of climate change on balsam fir, a short-lived, shade-tolerant conifer that dominates much of the understory in the Acadian forest and is an important component of lynx habitat in the Northern Maine Unit. McWilliams *et al.* 2005 (p. 8) noted that balsam fir increased in Maine's forest inventory in the early 2000s because this species seems to respond favorably to frequent disturbance. Forest models projected increases in spruce-fir biomass over the next century because of partial harvesting and periodic budworm outbreaks, but did not take climate change into consideration (Simons-Legaard *et al.* 2013, entire). In contrast, Iverson *et al.* 2008 (p. 400) identified balsam fir as the tree species in Maine most sensitive to a warming climate, and they projected large declines, with only 29 percent (low emissions) to 16 percent (high emissions) persisting by the end of the century. Climate change will influence precipitation and temperature, forest management strategies, and forest disturbance (fire frequency and spruce budworm), all of which will interact in complex ways to influence balsam fir at the southern edge of its range. Carter (1996, pp. 1092-1093), Iverson *et al.* (1999, pp. 400, 403), and Goldblum and Rigg (2005, p. 2714) documented balsam fir growth rates and growth potential would decline under likely climate warming scenarios (about a 2.2°-2.8°C (4°-5°F) temperature increase by the end of the century and reduced snow conditions). Some have projected the extirpation of spruce-fir forest types in the Great Lakes States (Scheller and Mladenoff 2005, entire) and New England (Iverson *et al.* 2008, entire. 403). Balsam fir has prolific seed production following forest disturbance such as harvesting (Seymour 1992, p. 217), and has proliferated under the current climate and forest management regime dominated by partial harvesting (Olson *et al.* 2013, entire). Balsam fir is a relatively short-lived tree (about 100 years), and is unlikely to persist long if climate change affects seed and germination rates. Given anticipated climate changes, especially early snow melt and low spring precipitation, fir may increase for the next few decades but is unlikely to regenerate in the future Maine forest (Simons-Legaard 2015, *pers. comm.*).

Vegetation Management - Habitat suitable for lynx is expected to decline in the future (see Regulatory Mechanisms section above). By 2020, all of the extensive areas that were clearcut in the 1970s and 1980s will be greater than 35 years of age and no longer likely to support high hare densities. For the foreseeable future, partial harvesting will continue as the primary means of forest management. Although partially harvested forests with well-developed understory structure may provide foraging opportunities via increased prey access (Fuller *et al.* 2007, 1984-1985), snowshoe hare densities are approximately 50 percent less in landscapes dominated by partially harvested stands (Robinson 2006, pp. 5-37; Fuller and Harrison 2010, p. 1276). Thus changing forest management practices have and will continue to reduce landscape hare density possibly below levels that can support lynx.

Sources of uncertainty concerning future habitat conditions in northern Maine include changes in forest policy, timber harvesting methods, changing timberland ownership, response to budworm outbreaks, and timber markets - all of which have occurred in the recent past and will undoubtedly shape forest management in the future (Simons-Legaard *et al.* 2016, p. 8). Currently, the landscape is owned primarily by financial investors who may be less inclined to intensively manage for spruce and fir after the next outbreak of the spruce budworm (Wagner *et al.* 2015, p. 4).

The dramatic shift from clearcutting to partial harvesting presents a challenge for lynx conservation in this unit for the next several decades (Legaard *et al.* 2015, p. 21). Lynx habitat is expected to peak and then remain stable through about 2012-2020 and then decline (Simons 2009, pp. 153-165, 202-220; Simons-Legaard *et al.* 2016, p. 6). After 2020, aging of the former clearcuts and extensive partial harvesting are projected to result in a 50 to 65 percent decline in lynx habitat by 2032 (Simons 2009, p. 217). Lynx habitat will decline from about 9.5 percent of the landscape (current condition) to about 5.0 percent of the landscape (Simons-Legaard 2016, fig. 8, p. 10). By 2032, the Northern Maine Unit may support less than half the number of resident lynx that it does today (Simons 2009, pp. 209, 217).

In the future, lynx habitat is projected to become fragmented into smaller, isolated parcels and shift southward into areas currently occupied by bobcats and fishers, where snow conditions are unlikely to favor lynx occupancy (Simons 2009, pp. 153-165; Simons-Legaard *et al.* 2016, pp. 1, 6; Simons-Legaard 2016, p. 8). By 2022, the number of patches of high-quality hare habitat is modeled to increase by 57 percent, but the average size of patches would decline by 87 percent and patches would become more isolated (Simons-Legaard *et al.* 2016, pp. 5-6). The proximity index of high-quality habitat patches is expected decline by 78 percent within lynx home ranges. Although lynx habitat in this geographic unit is currently peaking, fragmentation may diminish its future ability to support as many resident lynx as it does currently (Simons-Legaard *et al.* 2016, p. 8).

Beyond 2030, assumptions concerning future climate change, land ownership, and harvest rates introduce greater uncertainty. The most optimistic forest management models (greatest harvest rates, no climate change, no spruce budworm) project that lynx habitat will likely decline over the next few decades then gradually increase to about 10 percent of the landscape by 2060 (Simons-Legaard 2016, fig. 8, p. 9). Other models (lowest harvest rates, no climate change, no spruce budworm) project about 5 percent of northern Maine will likely have high-quality hare habitat from 2030 to 2060 (Simons-Legaard 2016, fig. 8, p. 9), although the habitat will be much more fragmented and patch sizes will be smaller (Simons-Legaard *et al.* 2016, entire). This could represent a return to conditions similar to those that occurred historically prior to the landscape-scale clearcutting that created the current condition, perhaps resulting in commensurate changes in Maine's lynx population.

A shift toward managing private timberlands as softwood plantations could offset losses in spruce-fir and become a form of adaptation to climate change effects of reducing spruce-fir forest types. Jack pine plantations are extensive in adjacent New Brunswick (Etheridge *et al.* 2005, p. 1966). A forest company that has planted extensive spruce plantations in New Brunswick recently purchased nearly 4,047 km² (1,563 mi²) of forestland in northern Maine where it is doing the same. Spruce plantations are becoming more common on this ownership in Maine, but not on others. Stand structure and intensive management of plantations are highly variable (e.g., pruning, thinning, herbicide treatments), thus hare densities and use by lynx vary (Roy *et al.* 2010, entire). Hares can achieve higher densities in plantations depending on the amount of lateral (horizontal) cover, but for shorter periods of time; about 10 to 17 years after

cutting and planting in New Brunswick (Parker 1984, p. 163) and 15 to 25 years in Quebec (Roy *et al.* 2010, p. 585). This is in contrast to about 15 to 35 years in naturally regenerating spruce-fir stands after harvest (Simons-Legaard *et al.* 2016, p. 4). The future of plantations in the northern Maine unit is uncertain. Most investment landowners have short-term investment horizons and are unlikely to invest in plantations.

Natural stand-replacing disturbances in this unit are rare and infrequent and, other than spruce budworm outbreaks, are unlikely to significantly affect future habitat conditions (Hoving *et al.* 2004, p. 292). At its peak in 1975, budworm affected nearly all of Maine's 8 million acres of spruce and fir with greatest mortality (up to 49 percent) of balsam fir and less for the spruce species (Livingston 1998, pp. 26-27). A very large outbreak has thus far defoliated 60,700 km² (over 23,000 mi²) of spruce-fir in southern Quebec, immediately north of Maine (Wagner *et al.* 2015, pp. 2-3), and it is projected to expand into northern Maine in 2018-2021, potentially putting much of Maine's 23,472 km² (9,063 mi²) of spruce-fir stands across the State at risk of defoliation. However, despite the severe defoliation of spruce-fir forests in southern Quebec, some project a weaker outbreak in Maine because spruce and fir trees are younger and less susceptible and there is a higher hardwood component in northern Maine forests (Wagner *et al.* 2015, p. 18-22). A typical outbreak lasts for a decade.

Forest management strategies for addressing the coming budworm outbreak vary and include applying insecticides (although land area sprayed is expected to be small compared to the previous outbreak), pre-emptively cutting mature spruce-fir before defoliation, stopping precommercial and commercial thinning, and salvaging dead and diseased trees (Wagner *et al.* 2015, pp. 38-48). The nature and aggressiveness of forest management response to budworm outbreaks could greatly affect future outcomes for lynx habitat (see section 4.2.1). The next budworm outbreak and subsequent forestry response is a disturbance agent that may accelerate changes in forest composition influenced by climate change, especially toward increased northern hardwood and reduced spruce-fir. The nature of land ownership is greatly changed from the 1970s and 1980s, and landowner response is expected to be diverse depending on their objectives and investment horizons. The pending budworm outbreak cast additional uncertainty on the status of lynx habitat in this geographic unit beyond 2030.

Climate change, forest management and budworm outbreaks will interact to influence the future trajectory of spruce-fir forest in Maine. All 3 variables have yet to be modeled simultaneously (Legaard 2016, *pers. comm.*). Assuming current forest management trends persist to the end of the century, spruce-fir dominated forest is expected to continue to decline (Legaard *et al.* 2013, entire). The combination of budworm-induced mortality and salvage harvesting will have a negative effect on spruce-fir (Legaard *et al.* 2013, entire). However, after a budworm outbreak the biomass and area of mixed-hardwood/softwood forest would be expected to increase through this century primarily because of the proliferation of regenerating balsam fir (see discussion above; Legaard *et al.* 2013). Mixed forests having a high (greater than 50 percent) hardwood component are not believed to support high hare densities (Scott 2009, p. 109) or to be preferred by lynx (Vashon *et al.* 2008b, pp. 1492-1493). It is uncertain whether lynx can adapt to lower landscape hare densities associated with mixed hardwood-softwood forest. They

may persist, but at lower densities as they currently do in the western units of the DPS. However, the probability of persistence is further diminished by deteriorating snow conditions and potentially increased populations of bobcats and other competitors.

Wildland Fire Management - Susceptibility of the northern Maine unit to fire may be enhanced by a severe spruce budworm outbreak because of the amount of dead and dying spruce-fir (Stocks 1987, entire), although there were no large fires after the last outbreak. Fire risk is currently very low in this unit and a continuous decrease in fire frequency is predicted with climate change in eastern Canada because of increased precipitation and decreased drought (Bergeron and Flannigan 1995, entire; Flannigan *et al.* 1998, entire). Climate is expected to become more variable (i.e. wider extremes of summer drought and precipitation) during the next century (Gregory & Mitchell 1995, entire; Gregory *et al.* 1997, pp. 684-685), which could create fire conditions in unusually dry years (Flannigan *et al.* 1998, p. 475). Maine's policy is to immediately suppress wildfire, thus large, stand-replacing fires are expected to be infrequent in this region in the future. Notable large fires in Maine include a 1.2 million-ha (3 million-ac) fire in 1825 and an 81,000 ha (200,000-ac) fire in 1947.

Habitat Fragmentation - The future of the 40,470-km² (15,630-mi²), sparsely populated "North Woods" of Maine is highly uncertain and has been the subject of intense public debate (Baldwin *et al.* 2007, entire). Land use and zoning in the state's "unorganized townships" are the responsibility of the Land Use Planning Commission (LUPC) in the Maine Department of Conservation. The LUPC revised its Comprehensive Land Use Plan (Maine Land Use Regulation Commission 2010, entire), and described principal values in guiding future land management decisions: maintaining working forests, provide for traditional recreational opportunities, protect high-value natural resources, and encourage long-term conservation. The North Woods has long been considered a public resource or "commons," even though privately owned (Judd 2007, p. 9). This land was traditionally owned by a few large timber companies, but since the 1980s there has been turnover in ownership largely by investments companies and subdivision of large parcels (Hagan *et al.* 2005, entire). Financial investors, primarily Real Estate Investment Trusts (REITS) and Timber Investment Management Organizations (TIMOs), focus on maximizing the asset value of timberlands and are increasingly likely to seek revenue from non-timber resources if they generate a higher return. These new owners operate over relatively short (5- to 15-year) time horizons and are willing to consider multiple means of monetizing their asset, including development and real estate sales (Legaard *et al.* 2013, entire). If left unchecked, these pressures may continue to promote dispersed development throughout this region. Parcelization and subdivision has increased, particularly in the southern third of the jurisdiction (Maine Department of Conservation 2010, p. 72-73). The LUPC has limited ability to address stressors on Maine's North Woods, including resale and subdivision trend. This trend is likely to continue into the foreseeable future and will make management of large, forested landscapes for lynx even more difficult.

Historically, development has stayed mostly on the edges of the North Woods jurisdiction with the exception of scattered seasonal dwellings and sporting camps in the interior, but this could change in the future. Between 1971 and 2005, the LUPC permitted 8,136 new dwellings in

unorganized townships, increasing the number of residences by 66 percent during this time period (Maine Land Use Regulation Commission 2010, p.80). Between 1971 and 2005, the LUPC also issued 1,353 development permits for new uses scattered throughout the unorganized townships (Maine Land Use Regulation Commission 2010, pp. 97-99), with most (42 percent) being recreational facilities (boat launches, campsites, gatehouses, recreational lodges). Most development has occurred in areas that abut organized communities and near public roads. Within the interior, most development has occurred along lakeshores and other waterfront. However, the amount of hillside and ridge development is growing and this trend is likely to continue (Maine Land Use Regulation Commission 2010, p. 136), which will likely further fragment lynx habitat.

We have an incomplete understanding of the effects of outdoor recreation on lynx and their habitat (ILBT 2013, p. 80). Future trends in outdoor recreation in northern Maine are also uncertain (Vail 2007, entire). A portion of the North Maine Woods is a gated road system that encompasses about 1.4 million ha (3.5 million ac). Visitation by outdoor recreationists is currently about 175,000 per year and declining. Likewise, visitors to Baxter State Park and the Allagash Wilderness Waterway have declined (Vail 2007, p. 107). Aside from a vigorous discussion of the recently-designated Katahdin Woods and Waters National Monument or a master tourism plan for the area (Vail 2007, pp. 112-113), there could be stagnant or declining participation in traditional outdoor recreational activities in the future (Vail 2007, p. 107). Alternately, increased numbers of second homes and resorts could increase visitor numbers in the future. Snowmobiling may be an exception and has risen in popularity in northern Maine, but it too may decline because of declining snow (see section 3.2). The effects of new or expanded downhill ski development on fragmentation of lynx habitat are expected to be minimal. Future trends in outdoor recreation and associated effects on lynx, hares, and their habitat in northern Maine are uncertain.

Within the last 5 years, 2 landowners developed concept plans for rezoning for large-scale development of hundreds of house lots and resort development within designated lynx critical habitat. Under one concept plan, 975 houses and 2 resorts would be constructed on about 14 km² (5.5 mi²) and a 1,469-km² (567-mi²) conservation easement would be established. A second concept plan would allow development on about 8 km² (3 mi²) of land and establishment of a 59-km² (23-mi²) conservation easement. Although these developments have not been built, they may portend future trends in land use.

Energy production is emerging as a potentially significant economic factor in this unit, with the potential for grid-scale industrial wind and solar power, biomass, biofuels, and other energy sources. Wind energy resources are high within the lynx critical habitat (National Renewable Energy Laboratory 2010²⁵), and wind development in the lynx critical habitat are likely to accelerate in the foreseeable future. Two large wind energy projects are being considered in designated lynx critical habitat in this unit; if built, each would cover about 450-650 km² (180-250 mi²) and become 2 of the largest such projects in Maine. Mining is not a traditional land use

²⁵ http://apps2.eere.energy.gov/wind/windexchange/wind_resource_maps.asp?stateab=mecitation; last accessed 5.25.2016.

in this unit, but a large mining operation is being considered within designated lynx critical habitat. Extraction operations for gravel (for road building) are widely-scattered throughout the unit.

The area designated as lynx critical habitat is heavily-roaded, particularly with forestry roads. While accurate numbers are difficult to obtain, approximately 1,500 miles of public roads and over 20,000 miles of private roads exist within unorganized areas of Maine (Maine Department of Conservation 2010). There has been discussion of an east-west limited access highway through northern Maine and extending Interstate 95 north from Houlton to Presque Isle, which, if constructed, would further fragment habitat (Maine Department of Transportation 1999; Beck *et al.* 2012, p. 38).

An increasing area of the designated lynx critical habitat in this unit is likely to be placed under conservation easements that will limit future development and fragmentation of lynx habitat. Maine has the largest amount of land under easement of any state, and there are about 8,094 km² (3,125 mi²) of conservation easements in lynx habitat in northern Maine (Pidot 2011). Continued expansion of areas under conservation easement is uncertain and will depend on willing landowners and funding available for purchase of easements. Conservation easements often include abandonment of some development rights, but they may allow for wind power development and other land uses that may not be compatible with lynx conservation. Easements in Maine allow forest management, but they rarely prescribe specific management that would benefit lynx and other species of conservation concern. If market conditions continue, trends toward forest certification will likely continue in Maine for the foreseeable future. Currently, 8 million acres are enrolled in Maine by SFI and FSC (Wagner *et al.* 2016, p. 31). Certification has the potential to address lynx management in the future.

The Core Team believes that all development trends portend increased loss and fragmentation of lynx habitat in the Northern Maine Unit. As habitat is lost and fragmented as a result of development and forest maturation and management, it will become increasingly difficult to influence landscape-scale forest management that could benefit lynx. However, whether (and if so, when) future development may result in population-level impacts to lynx in this unit is uncertain.

Conclusion

After reviewing the scientific literature concerning snow and climate change and acknowledging other potential stressors unique to this unit (e.g., lack of forest planning for lynx, land ownership turnover, and development pressures), the Core Team believes that lynx habitat and numbers in Maine will diminish substantially in the future. We believe the number of resident lynx in Maine is at an historically (unnaturally) high level and will likely decrease over the next several decades, perhaps to levels more like natural historical conditions, and perhaps (but with increasing uncertainty) to even lower numbers in the more distant future (end of this century). Given current trends (diminishing snow conditions, extensive partial harvesting and fragmentation of spruce-fir forest, possible pelage mismatch for hares, increasing populations of

bobcat and fishers in a lower-snow environment), we believe landscape level hare densities are likely to decline in northern Maine. Extended periods of lower hare numbers would likely reduce the number of lynx and the probability that this unit would continue to support a persistent resident lynx population in the future.

We concur with expert assessments concerning trends in forest management, but we also note that development pressures in northern Maine did not receive much discussion at our expert elicitation workshop. We believe development pressures (residential and commercial development, energy development, transmission lines, roads, mining) may increasingly become competing land uses on private lands in northern Maine. We also expect continued turnover and subdivision of private forest lands in northern Maine, which could accelerate opportunities for non-forestry land uses. Turnover in land ownership has provided opportunities to conserve some areas of the North Maine Woods through purchase of conservation easements and fee title acquisitions, including a new Katahdin Woods and Waters National Monument. However, conservation easements do not fully protect these lands from some kinds of development that could adversely affect lynx and their habitat. For example, many conservation easements allow large-scale, industrial wind power development. We conclude that various forms of development in northern Maine will continue in the future.

The Core Team believes lynx in Maine would be more exposed to potential adverse impacts in a future scenario without Federal listing. The lynx is not State-listed in Maine but it is considered a species of special concern. There is rarely a nexus for Service review of forestry projects under section 7 of the ESA (i.e., no Federal funding or permits are typically required for forest management on private lands). Nevertheless, because of its Federal listing, the Canada lynx are a priority species for planning by Federal, Tribal, State, and private forest landowners. Although few private landowners have thus far made formal commitments to intentionally manage their forests for lynx, by virtue of their Federal listing status they at least consider the possibility of doing so in the future. This is particularly true of landowners who must plan for Federal listed species as a requirement of their enrollment in green certification programs. Without Federal listing, there would be no incentive or motivation for private forest landowners to change the current paradigm of partial harvesting and intentionally engage in forest management to benefit lynx. With current Federal listing, there is a nexus for the Service to review other projects in northern Maine (e.g., Army Corps of Engineers permits for wetland impacts); for new highways, transmission lines, large-scale energy development, mining, and residential and commercial development. Without Federal listing, few of these projects would consider lynx. Critical habitat has been an important consideration in the Federal review of the aforementioned kinds of development projects. Critical habitat also has had a positive influence on land conservation in northern Maine, with land trusts and non-governmental organizations using the lynx and their critical habitat as justification for seeking funds for conservation easements. This justification for habitat protection would no longer be valid if the DPS was not Federally-listed. The Core Team concludes that a future scenario without Federal listing would result in increased habitat loss and fragmentation and would result in reduced justification for habitat protection initiatives in northern Maine.

Lynx would be at greater risk without ESA section 9 prohibitions against take. There is currently a closed season on lynx, but it is uncertain whether legal trapping of lynx would resume in Maine if the DPS was not listed. If the DPS was not listed, it is possible that State-managed trapping could resume in this and perhaps other geographic units. We expect that would only occur if scientific evidence strongly suggested the presence of a harvestable surplus of lynx and that harvest quotas would be carefully managed to ensure that the viability of resident lynx populations would not be diminished. If the DPS was not listed, Maine's incidental take permit for trapping would not apply, and it is possible that some protective measures to minimize injury, take, and mortality of lynx could be diminished. Habitat mitigation for lethal take of lynx associated with the Maine trapping HCP also would cease. About 10 lynx have been illegally shot and reported or otherwise discovered since listing. Illegal shooting and non-reporting could increase without Federal protection. We believe several high-profile Federal law enforcement cases have helped to reduce illegal shooting of lynx.

After considering the lynx expert's opinions and the best available scientific information, the Core Team is less optimistic than the experts regarding the long-term (end-of-century) persistence of resident lynx in this unit. All potential stressors – forest management, climate change, habitat loss and fragmentation, and development – are increasing in frequency, intensity, and extent. The amount of high-quality hare and lynx habitat created by clearcutting in the 1970s and 1980s recently peaked at unprecedented high levels that are unlikely to be achieved again. Because of state law, forest management has shifted dramatically away from clearcutting to many forms of partial harvesting, which on average support less than half the hare densities of regenerating clearcuts. Forest land ownership has, and continues to change, further subdividing private forest lands. Furthermore, hare densities have declined by half and have remained at these lower levels. Lynx habitat in the next few decades will shift south to areas that will be more influenced by climate change and northward range expansion by bobcats. Thus, we conclude that the carrying capacity to support lynx is diminishing, and the lynx population will decline as the quantity and quality of boreal forest habitat declines. There are few commitments by private forest landowners to manage specifically for lynx conservation.

After reviewing the best available scientific information, we believe that climate change will be a significant stressor to lynx in the Maine unit; perhaps more so than expressed by experts. Unlike other units, as snow condition decline there is little potential for elevational refugia for lynx in Maine. Spruce-fir is being replaced by northern hardwoods because of climate change. Frequent forest cutting and disturbance, including a pending spruce budworm outbreak, could accelerate conversion to northern hardwoods. We acknowledge that the rate of spruce-fir decline is uncertain, but note that some of the science reviewed indicates the spruce-fir forest type could nearly disappear from Maine by late-century under both low and high emissions scenarios. Climate change models portend declining snow conditions from low- to high-emissions. Because increases in temperature are thus far tracking high emissions scenarios we are less optimistic for snow conditions that favor lynx by mid- to late-century. In the past decade, interest in development has increased in lynx critical habitat, especially proposals for large-scale residential and resort development and extensive wind energy development that could cover hundreds of square miles. We conclude that these stressors, individually and cumulatively,

indicate diminished populations of lynx and their habitat. If these stressors are not abated, we believe that the probability of persistence will be lower by mid-century and that lynx will have a greater likelihood of extirpation by the end of the century than projected by experts.

5.2.2 Unit 2 - Northeastern Minnesota

Expert Projections of Lynx Persistence

The experts that we consulted indicated an initially high and subsequently declining probability of persistence of resident lynx in Minnesota, with increasing uncertainty through the end of the century (Lynx SSA Team 2016a, pp. 37-38). Near term drivers of the projected decline were climate-driven reduction in snow quality, quantity, and persistence; potential increased competition from bobcats; and forest insects. Long term drivers were climate-driven loss of spruce-fir forests; further reductions in snow quality, quantity, and persistence; potential competition from bobcats; and potential increases in wildfire activity.

Climate change was primarily associated with loss of boreal forest but also could potentially increase disease or insect outbreaks, and is likely to affect the amount of precipitation falling as good quality snow in the area of the state supporting lynx habitat. We heard varying prognoses from experts on the speed at which climate-induced loss of boreal forest will occur. The scientific literature suggests (and 1 of the climate change experts indicated) that loss of spruce-fir could occur relatively quickly in the Midwest and Northeast (but possibly more slowly elsewhere in the DPS because of potential elevational refugia), and all noted that an increase in northern hardwood composition of the forest is already occurring. Connectivity to lynx in Ontario reduces the likelihood of local extirpation in this geographic unit, but the likelihood would increase if connectivity was to become compromised in the future if habitat recedes northward and becomes increasingly fragmented on both sides of the border, as expected with continued climate warming.

Despite uncertainty, experts generally agreed that climate-related loss of favorable snow conditions (amount, consistency, and duration), loss of boreal forest, and potentially increased bobcat competition and hybridization are likely to reduce the probability of lynx persistence in this unit. Experts expressed uncertainty about the likelihood and severity of future insect outbreaks (and how this could affect future lynx habitat) and the potential introduction and spread of diseases.

Taking all of these factors into consideration, experts provided “most likely” persistence probabilities of 88 to 100 percent (median = 96 percent) in the near-term (year 2025), 60 to 90 percent (median = 80 percent) at mid-century, and 10 to 60 percent (median = 35 percent) at the end of the century (fig. 11). As they did for most other geographic units, all experts indicated an initially high and subsequently decreasing likelihood that resident lynx will persist in this unit, with uncertainty increasing substantially over time.

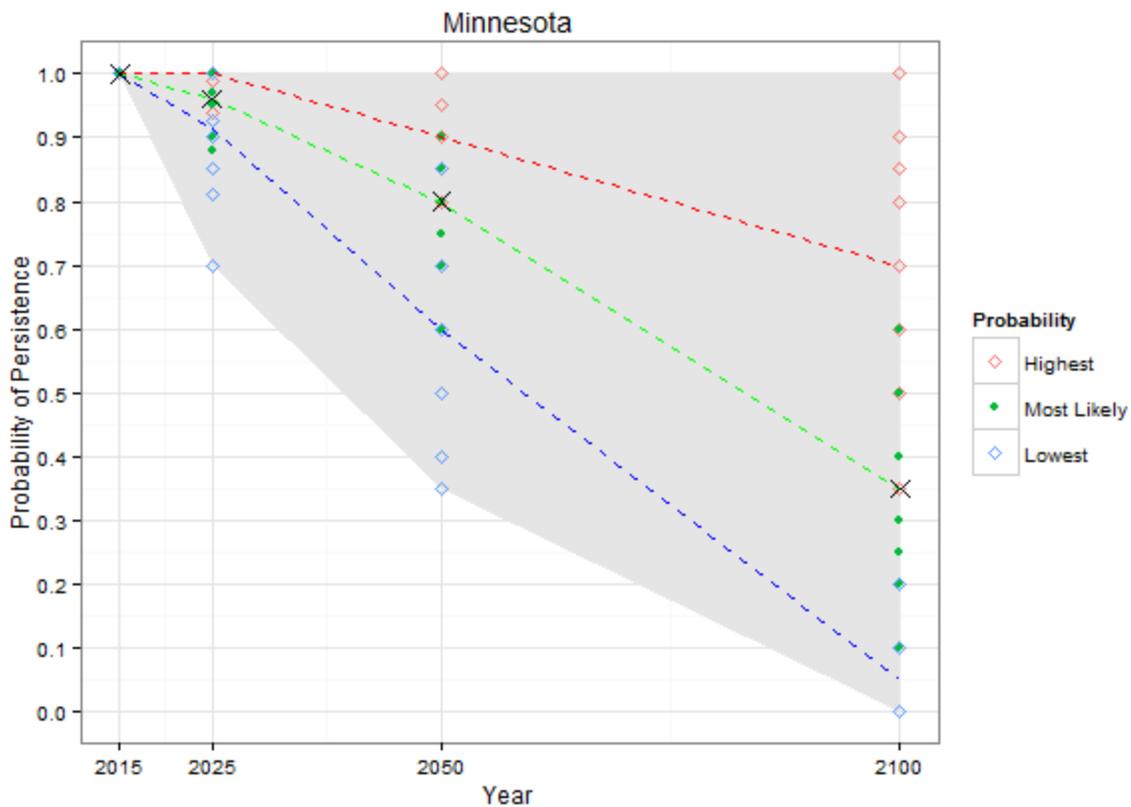


Figure 11. Lynx expert estimates of the probability that the Northeastern Minnesota Geographic Unit will continue to support resident lynx in the future (at years 2025, 2050, and 2100).

Service Evaluation of Factors Potentially Influencing Future Conditions

Regulatory Mechanisms - In Minnesota, the vast majority of lynx habitat that supports a long-term persistent lynx breeding population is administered by the SNF. This area includes designated critical habitat (79 FR 54782). The SNF consults with the FWS to consider the effects of any projects on lynx and its critical habitat and is anticipated to do so as long as the species is listed under the ESA. The SNF is currently implementing the 2004 SNF Plan (USFS 2004a, entire), which has direction based on the LCAS (Ruediger et al. 2000, entire) and the Canada Lynx Conservation Agreement (CA) between the Forest Service and the Service (USFS and USFWS 2000, entire), for all forest activities that occur within LAUs. Active management of forest lands can maintain, restore, or create lynx habitat, and the SNF has a long-term commitment to doing so. If the SNF continues to follow vegetation and wildland fire management and other applicable recommendations in accordance with the LCAS (including consideration of new scientific information as it becomes available) in its Forest Plan, we expect that several risk factors will continue to be minimized and managed to promote the conservation of lynx within the SNF into the future. Management of lynx and its habitat on SNF land will remain in place until the forest amends or revises its LRMP. We expect that management

direction for lynx addressing vegetation management, wildland fire management, and habitat fragmentation on National Forest System lands will be incorporated into the revised or amended Forest Plans (LRMPs). Although management of lynx habitat and lynx conservation efforts on the SNF could change in the future if the DPS was not listed, the species would be placed on the Regional Forester's Sensitive Species list for a minimum of 5 years, which gives it a higher priority than other species for monitoring and management during that time.

The Chippewa and the Chequamegon-Nicolet National Forests occur outside the Northeastern Minnesota geographic unit and the area considered to be core lynx habitat (i.e., where lynx are persistent and are reproducing). However, because lynx occasionally occur on these forests, the Forest Plans for both also include direction based on the LCAS and the CA between the Forest Service and the Service for all forest activities that occur within LAUs (USFS 2004b, entire; USFS 2004c, entire). These 2 forests consult with the FWS to consider the effects of any projects on lynx and are anticipated to do so as long as the species is listed under the ESA. It is unclear if lynx habitat management and conservation efforts on these national forests would change if the DPS was not listed in the future.

Additionally, the Minnesota Department of Natural Resources (MNDNR) manages approximately 36 percent of the lynx habitat in this unit, and privately-owned lands make up about 16 percent of the unit. Under the Sustainable Forest Resource Act of 1995 (revised in 2014), the Minnesota Forest Resources Council (MNFRC) has developed guidelines for site-level timber harvesting and forest management (MNFRC 2013, entire; MNFRC 2014, entire). These voluntary guidelines are intended for private and State landowners and include some general recommendations for wildlife but are not specific to lynx (MNFRC 2014, pp. 4-5). It is expected that the MNFRC guidelines will remain in place into the future and that voluntary actions will continue. Private landowners, however, do not have an official commitment to land management. We cannot say with any certainty what proportion of privately owned land will follow those guidelines into the future, because following the guidelines is voluntary. The MNFRC guidelines are less comprehensive and are not specific to lynx, and therefore may not be as beneficial to lynx and lynx habitat as the lynx and hare specific direction followed by the Forests.

The NPS manages Voyageurs National Park, which is also within the Minnesota unit. Voyageurs National Park protects an area of 882 km², of which 534 km² (62 percent) is covered by forests and other uplands (Moen *et al.* 2012, p. 348), but does not have lynx specific direction in its management plan (NPS 2002, entire). The National Park consults with the FWS to consider the effects of any projects to lynx (NPS 2002, p. 26) and is anticipated to do so as long as the species is listed under the ESA. Lynx documented on and near Voyageurs National Park are probably transient animals (Moen *et al.* 2012, p. 348).

Approximately 1 percent of the Minnesota unit is managed by the Grand Portage Band of Chippewa, which has been actively working on lynx conservation since 2004. Timber sales and harvest practices on the reservation follow an integrated plan for priority wildlife management, sustainable economic development, and recreational uses. The Band's timber management

practices benefit snowshoe hares (Deschampe 2008, entire) and are expected to continue into the future.

In response to a 2008 court ruling, the MNDNR drafted a plan (currently under review by the Service) to minimize the likelihood that lynx would be incidentally trapped during otherwise legal trapping of other furbearers in Minnesota. As described above in section 3.1.2, the MNDNR designated a Lynx Management Zone (LMZ) where it enforces special trapping regulations to minimize the incidental take of lynx (MNDNR 2016a, pp. 53-55). In 2015, the MNDNR also issued emergency trapping rules in the LMZ mandating additional restrictions on the types of traps that may be used (MNDNR 2015, entire) to further reduce the likelihood of incidental take. If the DPS was not listed, we expect that the State would continue efforts to reduce incidental trapping of lynx. Although we consider it unlikely, it is possible that State-managed trapping of lynx could resume in the future if the DPS was not listed. If that were to occur, we assume the State would proceed only after demonstrating the level of harvest the population could sustain and carefully developing, enforcing, and monitoring a strict trapping quota system to ensure that harvest level would not be exceeded.

Climate Change - The direct and indirect effects of climate warming are expected to affect lynx in Minnesota (Siren *in* Lynx SSA Team 2016a, pp. 15 and Moen *in* Lynx SSA Team 2016a, p. 19) and could restrict their future range. As described in section 3.2, new information on regional climate change and potential effects to lynx habitat that has become available since the DPS was listed suggests that lynx distribution and habitat is likely to shift northward in latitude and upward in elevation within its currently occupied range as temperatures increase. Because of its generally flat topography, this geographic unit presents little opportunity for elevational migration of lynx and lynx habitat. Other potential impacts of climate change include (1) diminishing snow depth, quality, and duration, perhaps resulting in increased competition from bobcats, coyotes, and other terrestrial hare predators and increased hybridization with bobcat, (2) conversion of spruce-fir to northern hardwoods, and (3) potential future isolation of resident lynx in this unit because of diminishing forest conditions in southern Ontario.

Gonzalez *et al.* (2007, pp. 8, 12-19) predicted the persistence of boreal forest and historical (1961-1990) snow suitability for lynx (95 percent historical and future probability of suitable snow) in this unit through 2071-2100, and suggested that the SNF could provide a potential refugium for lynx. Notaro *et al.* (2015, pp. 1668-1669) projected changes in lake effect snowfall using downscaled climate models (Abdus Salam International Centre for Theoretical Physics (ICTP) Regional Climate Model version 4 (RegCM4; Elguindi *et al.* 2011 and Giorgi *et al.* 2012 as cited in Notaro *et al.* 2015) for the Great Lakes Basin. Siren (*in* Lynx SSA Team 2016a, p. 15) stated that climate models show an increase in lake effect snow in the eastern Great Lakes until 2050, with a decline later in the century, with an overall decline in the amount and duration of snowpack in the Midwest.

Historical lynx records occurred in areas with at least 4 months (120 days) of continuous snow coverage (Gonzalez *et al.* 2007, p. 7). In northern Minnesota from 1959-1979, the number of days with snow cover ≥ 2.5 cm (1 in) ranged from 130 to 160 days; ≥ 15 cm (6 in), from 85 to

130 days; ≥ 30 cm (12 in), from 50 to 100 days; and ≥ 61 cm (24 in), from 10 to 30 days (Kuehnast *et al.* 1982, pp. 7-9). In the future, Notaro *et al.* (2015, p. 1675) projected a general reduction in the frequency of heavy lake-effect snowstorms during the twenty-first century, with the exception of projected mid-century increases around Lake Superior when local air temperatures are expected to remain low enough for precipitation to fall largely in the form of snow. The snow season in the Great Lakes basin is likely to become substantially compressed during the twenty-first century with dramatic increases in rainfall (Notaro *et al.* 2015, pp. 1676-1678). The Minnesota unit may be more vulnerable to snowpack loss due to lack of elevational refugia (Siren *in* Lynx SSA Team 2016a, p. 15).

Normal annual snowfall from 1981-2010 in northeastern Minnesota ranged from 140 to 241 cm/yr (55 to 95 in/yr)²⁶ and is projected to decline across the Great Lakes Basin in the future (Notaro *et al.* 2015, p. 1675). Snow conditions favorable for lynx (depth, consistency, and persistence) are projected to deteriorate in the Great Lakes Region. Notaro *et al.* (2015, pp. 1671-1674) projected a dramatic decline of Great Lakes ice cover that will become confined to the northern shallow lakeshores during mid-to-late winter by the end of the century. Ultimately, this leads to increased rainfall, not snowfall, as these projected reductions in ice cover and greater dynamically induced wind fetch lead to enhanced lake evaporation and total lake-effect precipitation (Notaro *et al.* 2015, pp. 1674-1678).

Climate change is projected to cause some northward contraction of boreal conifer forest in Minnesota (Gonzalez *et al.* 2007, p. 16, 18), with some potential loss of habitat at the southern portion of lynx habitat in the State but persistence of boreal forest in this geographic unit (Gonzalez *et al.* p. 2007, p. 19). Gonzalez *et al.* (2007, pp. 8, 13) also projected that northeastern Minnesota, including the SNF, would continue to have snow conditions suitable for lynx at the end of the century, and may serve as a refugium for lynx in the Lower 48 States. However, Moen (*in* Lynx SSA Team 2016a, p. 19) questioned this result, noting that the Gonzalez *et al.* model predicted a much larger distribution of suitable snow conditions than the area currently occupied by lynx in Minnesota. Moen presented preliminary snow modeling results that project snow conditions suitable for lynx could shrink significantly by 2055, be limited to extreme northeastern Minnesota by 2070, and could be entirely absent from the state by 2095 (Moen and Catton *in* Lynx SSA Team 2016a, p. 19). Frelich (*in* Lynx SSA 2016, p. 14), concluded that Minnesota could lose the boreal biome completely, possibly within the next 60 to 70 years, with unmitigated climate change. Similarly, Galatowitsch *et al.* (2009, pp. 2015-2016) concluded that the boreal forest of the Northern Superior Uplands (which encompass this geographic unit) will likely be lost by 2069 as a result of warmer summers and more frequent and longer droughts associated with climate change. If a refugium for lynx does persist in this unit in the future, it would likely only consist of the small area in Cook County (the extreme northeastern corner of the unit) with slightly higher elevations (518-701 m [1,700-2,300 ft]) than the majority of the area that is now considered lynx core habitat and would, therefore, support a much smaller number of resident lynx than likely occur in the unit now. Although uncertainties remain, as elsewhere, about the timing and magnitude of future climate-driven impacts, lynx

²⁶ http://www.dnr.state.mn.us/climate/summaries_and_publications/normals_snow_1981_2010.html; accessed 5.24.2016.

populations in Minnesota are expected to recede northward and decline over the next century (Lynx SSA Team 2016a, pp. 37-38).

Vegetation Management - Vegetation management similar to that conducted under current Forest Plans will likely continue into the future on Forest Service lands in Minnesota as long as the DPS is listed. These activities include timber harvest (thinning, clear-cutting, shelterwood, partial cut, and uneven-aged cutting); wildlife restoration projects that involve tree cutting, shearing, burning, seeding, and planting; prescribed burning for ecological purposes, hazardous fuel reduction, and site preparation; and mechanical site preparation. If the DPS is de-listed, the species would be placed on the Forest's Regional Forester Sensitive Species list for a minimum of 5 years, which gives it a higher priority than other species for monitoring and management during that time; however, it is unclear what the forest management would entail during or after that period of time.

Vegetation, timber, and minerals management authorized under current Forest Plans in Minnesota have the potential to adversely affect lynx and lynx critical habitat by reducing habitat quality for denning, foraging, and dispersal; disrupting travel, resting, and foraging patterns; disturbing denning females; and reducing habitat quality for lynx prey species, especially snowshoe hares. Depending on the timing, frequency, intensity, extent, amount, or other conditions, impacts may be variable among similar projects. Using the LCAS as a basis, the Forest Plans have incorporated a number of components that would reduce the risk of those impacts into the future. We expect that management direction for lynx addressing vegetation management on National Forest System lands in the future will be incorporated into revised or amended forest plans, using LCAS as a basis. Future Forest Plan revisions will likely maintain broad direction to design and implement vegetation management projects to maintain or restore conditions for lynx foraging and denning habitat and to maintain or improve juxtaposition of required habitat types and connectivity.

Over the long term, the Forest Plan will alter vegetation patterns on the landscape. Suitable hare habitat was predicted to decrease over time with implementation of the Forest Plan, but has actually increased since 2004 (USFWS 2011b, p. 51). Management activities that create unsuitable conditions for hare generally include clear-cut and seed tree harvest, and might include management-ignited fire, mechanical site preparation, salvage harvest, and shelterwood and commercially-thinned harvest, depending on unit size and remaining stand composition and structure. Suitable hare habitat is predicted to remain above the range of natural variation, which is essentially a description of conditions that existed prior to European settlement (1600 – 1900 A.D.) of the area (USFS 2004a, p. 105). Further, unsuitable habitat for lynx would vary only slightly with continued implementation of the Forest Plan and would remain distinctly below the maximum of 15 percent unsuitable in a decade prescribed in the LCAS and incorporated into the Forest Plan. Current (2010) unsuitable habitat levels are below what was predicted in the 2004 (USFWS 2011b, pp. 51-52). Because suitable habitat on National Forest System lands alone is such a high percentage within LAUs and the SNF is the majority landowner within most LAUs, we expect that in the future, the Forest would not approach the LCAS maximum of 30

percent of lynx habitat on all ownerships in an unsuitable condition within an LAU at any time, which would be ensured by corresponding guidance in the Forest Plan.

Wildland Fire Management - Unlike the Maine unit, the susceptibility of the Minnesota unit to fire may be reduced by periodic spruce budworm outbreaks. Measurable defoliation from spruce budworms has occurred in Northeastern Minnesota continuously since 1954 and is expected to continue into the future (Russell and Albers 2016, entire). Modeling to evaluate the relative strength of interactions between spruce budworm outbreaks and fire disturbances in the BWCAW showed that budworm disturbance can partially mitigate long-term future fire risk by periodically reducing live ladder fuel within the forest types of the BWCAW but will do little to reverse the compositional trends caused in part by reduced fire rotations there (Sturtevant *et al.* 2012, pp. 1286-1292). The SNF manages for wildfires through preventative measures such as fuels reductions, but does not manage for wildfires in the BWCAW. Natural successional changes and those associated with natural phenomena, such as wildfire or windstorms, are the dominant force in BWCAW ecosystems and are expected to continue to be in the future.

Habitat Fragmentation - Ravenscroft *et al.* (2010, p. 329) considers northeastern Minnesota forest landscape as largely unfragmented. The BWCAW remains intact and contiguous with Canada. Within the SNF, natural disturbances and vegetation management activities make up most of the annual human-caused fragmentation in actively managed portions of the Forest. These areas typically re-vegetate within 3 to 5 years, depending on the forest type and number and type of activities (USFS 2011a, p. 119). The SNF's Forest Plan (USFS 2004a, Appendix E) provides direction on limiting lynx habitat fragmentation and the Forest actively consolidates habitat through land acquisitions and exchanges. The Forest direction limiting habitat fragmentation is expected to continue as long as the DPS is listed.

Fragmentation, Development, and Human Access - Throughout the SNF and northern Minnesota, human activities have reduced connectivity between patches of suitable lynx habitat. Development for residential and commercial uses, as well as roads, railroads, and utility corridors have all interrupted linkage corridors. Still, much of the land within the Forest remains undeveloped and lynx habitat remains relatively intact and well connected. This is particularly true on the SNF, which has a "high standard" road density of roughly 0.45 mi/mi² outside the BWCAW.

Human access to lynx habitat occurs by foot and motorized vehicle, including recreational and off-road motor vehicles (RMVs and ORVs), and generally occurs on trails, low standard roads, and temporary roads developed for management operations, particularly timber harvests, and more recently, minerals exploration. While open, these roads provide access to lynx habitat. As northern Minnesota has become more developed and the human population has increased, the SNF has sustained increased visitation in recent years (USFS 2011a, p. 5) which increases the opportunity for human-lynx encounters, especially by trappers. Lynx are likely to continue to be incidentally trapped at the current rate as a result of continued access via low standard roads and trails on the Forest. Any corridor open to RMVs provides the potential for Forest visitors to incidentally trap, shoot, or collide with lynx. Temporary road construction for minerals

exploration projects may contribute significantly to temporary road densities and increase human access during the time the roads are being used. Temporary roads in mineral exploration projects may stay open longer (1-15 years) than those predicted by the Forest Plan EIS for resource management (1-5 years). If these sites are left accessible to the public, then human-lynx conflicts may increase. Additionally, intersections of new roads, closed temporary roads and/or roads open to the public are likely to become parking areas for cars, which would indirectly increase public access. Further, these corridors could increase potential competition through increased snow compaction. Effective road closures, however, may reduce the potential effects to lynx and their habitat.

Energy and Mineral Development - Mining (e.g., iron ore and taconite mining) is occurring at several locations in or near the lynx core habitat area in northeastern Minnesota (MNDNR 2016c, entire). Large-scale mining operations on non-Forest land could result in irreversible or irretrievable loss of lynx and hare habitat. Minerals exploration has increased and is occurring at many locations in northeastern Minnesota, which may lead to more large-scale mining projects. Vegetation clearing for minerals exploration projects may have temporary impacts to lynx and hare habitat at drill pad sites, although impacts from pad sites are expected to be minimal and temporary because the foot print of individual drill pads is typically small and the cleared land is expected to re-vegetate. Drill pad site preparation includes vegetation clearing on small patches of land (average of approximately 0.6 ha [1.6 ac]). This cleared land may provide snowshoe hare habitat after it has time to revegetate. Mineral exploration activities use existing Forest roads but also may require construction of new roads and may potentially add a significant number of road miles. Land exchanges associated with proposed mining sites could result in a loss of lynx and hare habitat under Forest management, but may also result in consolidation or gain of habitat with newly acquired lands (e.g. the Forest may be able to consolidate lands that they can then manage for lynx). Stone quarry extraction operations are also scattered throughout the unit (MNDNR 2016c, entire) and may impact lynx and hare habitats.

Conclusion

We concur with the expert panel that this unit is very likely to continue to support resident lynx in the near-term (2025) and mid-term (2050). However, after reviewing the scientific literature concerning climate change projections (diminishing snow conditions, northward contraction of boreal forest, lack of elevational refugia, potential for increased competition, disease, and insect outbreaks), some Core Team members were less optimistic about the future of lynx in Minnesota than the lynx expert panel. Depending on future emissions levels, the likelihood that this unit will continue to support resident lynx at the end of the century may be lower than the 35 percent (median most likely) estimate based on expert opinion. The threat for which the lynx was listed, lack of specific conservation direction, associated regulations, and lynx forest management planning has not been addressed on private lands in Minnesota, except through voluntary guidance. There is some uncertainty about the future of forest management and future development on private forest lands in Minnesota and in adjacent lands in Ontario, although there are some basic voluntary management guidelines for private lands in Minnesota. Further, if the DPS is de-listed, there is uncertainty whether the lynx direction on Forest lands would

continue into the future. It is projected that habitat will diminish and recede northward over the mid- to longer-term because of continued climate warming. Hybridization and competition with bobcat also may increase with diminishing snow conditions because of continued climate warming, and it is uncertain how insect outbreaks or disease may affect habitat and lynx in this unit.

The Core Team believes the Minnesota lynx populations would be expected to decline more rapidly in a future scenario without Federal listing. The lynx is designated as a species of special concern (MNDNR 2013, p. 2), a less restrictive designation than state threatened or endangered. There is a closed season on lynx, and it is expected that intentional take would continue to be prohibited until the population reached sustainable levels defined by the state. In Minnesota, the large proportion of lynx core area owned by the Forest Service provides a nexus for USFWS review of Forest projects under section 7 of the Endangered Species Act (i.e., there is rarely federal funding spent on forestry and no federal permits required for forest management on private lands), which would be lost post de-listing. Because of their Federal listing, Canada lynx are recognized as a priority species for planning by Federal, Tribal, State, and private forest landowners. Voluntary guidelines that consider the Federal listing status may guide private landowners to consider measures to help conserve listed species in the future. Without Federal listing driving voluntary conservation guidelines, however, there could be reduced incentive for some private forest landowners to intentionally engage in forest management to benefit lynx. With current Federal listing, there is a nexus for the USFWS to review other projects in northeastern Minnesota (e.g., Army Corps of Engineers permits for wetland impacts) for new highways, transmission lines, large-scale energy development, mining, and residential and commercial development. Without Federal-listing, the agencies funding or permitting these projects would not be required to consider impacts to lynx and designated critical habitat. The Core Team concludes that a future scenario without Federal listing would likely result in increased habitat loss and fragmentation and reduced incentive for habitat protection initiatives in northeastern Minnesota.

Lynx would be at greater risk without Endangered Species Act section 9 prohibitions against take. In a future scenario without Federal listing, Minnesota's incidental take planning effort for trapping would become moot, likely resulting in diminished protective measures to minimize injury, take, and mortality of lynx. Even with these prohibitions and protections, incidental trapping of 16 lynx has been reported in Minnesota since listing, resulting in at least 6 mortalities. It is uncertain if lynx would become a legally trapped furbearer in Minnesota if the DPS was not listed (although a legal wolf hunt was reinstated after that species was delisted in Minnesota, so regulated trapping could also be considered for lynx if the DPS was not listed). Seven lynx have been illegally shot and reported or otherwise discovered since listing. Illegal shooting and non-reporting could increase without Federal protection. Education efforts by Federal and State agencies and law enforcement agents may have helped to reduce illegal shooting of lynx in this unit. With a diminished snow regime, populations of bobcats could increase and expand north and eastward into areas currently occupied by lynx. Incidental take of lynx from bobcat trapping and hunting activities would likely increase without Federal listing. Similarly, fisher, fox, and coyote populations may increase in a diminished snow regime in

northern Minnesota and trapping would be expected to occur there that could lead to greater incidental take of lynx. We believe that despite a closed hunting and trapping season, incidental take would continue and possibly increase and could become a significant stressor to a population of lynx that could be substantially diminished between mid- and late-century.

After considering the best available scientific information, including the opinions of lynx experts summarized above, the Core Team was less optimistic than the experts about the long-term (end-of-century and beyond) likelihood that resident lynx will persist in this geographic unit. All potential stressors –climate change, habitat loss and fragmentation, mining and development – are increasing in frequency, intensity, and extent. Lynx habitat in the next few decades will likely shift north to areas that will be more influenced by climate change and northward range expansion by bobcats. Thus, we conclude that this unit's ability to support resident lynx will likely diminish in the future, and the lynx population will likely decline as the quantity and quality of boreal forest habitat declines. Although there are voluntary forest management measures to consider listed species on private forest lands, there are no commitments by private forest landowners to manage specifically for lynx conservation. We also believe that climate change will be a significant stressor to lynx in this unit; slightly more so than expressed by most of the experts. Snow depth and duration in the area currently supporting resident lynx are projected to decline significantly by the end of the century, likely to the detriment of both hare and lynx populations. Unlike most other units, as snow condition decline there is little potential for elevational refugia for lynx in Minnesota except, perhaps, a small area of slightly higher elevation in the extreme northeastern corner of the unit. The boreal forest in this unit is already being replaced by northern hardwoods because of climate warming. Frequent forest cutting and disturbance, including a potential insect outbreak, could accelerate conversion to northern hardwoods. We acknowledge that the rate of boreal decline is uncertain, but note that some of the modeling we reviewed suggests that the spruce-fir forest type could nearly disappear from Minnesota by late-century under both low and high emissions scenarios. Climate models also portend declining snow conditions under low- and high-emissions scenarios. Because increases in temperature are thus far tracking high emissions scenarios, we are less optimistic for snow conditions that favor lynx by mid- to late-century. In the past decade, interest in development has increased in lynx critical habitat, especially proposals for large-scale mining developments. Although we expect resident lynx to persist in this unit through 2025 and 2050, we conclude that the stressors described above, individually and cumulatively, could diminish lynx habitat and numbers in this unit. If these stressors are not abated, we believe that resident lynx in this unit will face a slightly greater risk of extirpation by the end of the century than was predicted by lynx experts.

5.2.3 Unit 3 - Northwestern Montana/Northeastern Idaho

Expert Projections of Lynx Persistence

When considering the probability that this unit would continue to support resident lynx in the future, experts noted that despite projected losses of favorable forest and snow conditions, climate models project that some boreal forest will persist in this unit and that it will maintain

some areas of suitable snow into the future. Experts also noted that lynx in this unit primarily occupy public lands, which are actively managed for lynx into the future. Experts also considered recent and projected future increases in wildfire frequency, size, and intensity (Lynx SSA Team 2016a, pp. 41-43). Additionally, because of its connectivity to lynx populations and habitats in Canada, its large geographic extent, and the relatively large number and broad distribution of resident lynx it is thought to support, experts felt that future extirpation of lynx from this unit from either reduced genetic health or a catastrophic event is unlikely (Lynx SSA Team 2016a, pp. 25-34).

Overall, experts assigned a higher likelihood of persistence in this unit compared to the other geographic units. Most lynx habitats in this unit occur on Federal lands that are managed for lynx conservation, but 1 expert noted that little has been done to document whether lynx are responding to this management. The recent sale of large tracts of private commercial timberlands in the central part of this unit to The Nature Conservancy has increased protection for lynx via conservation easements managed for lynx. Habitats in some areas should improve in the near future as previously cut or burned areas mature into dense stands. Unlike the Maine and Minnesota geographic units (but similar to most other western units), high elevations in this unit could buffer the effects of climate change by providing for the upslope migration of lynx habitats and snow conditions that climate models predict. However, this would result in even patchier and more isolated islands of habitat in high elevation areas that would be more prone to extirpation from catastrophic or stochastic events. Competition from coyotes and bobcats seem to be less of a concern for this unit.

This unit has unimpeded connectivity with Canada, but some experts questioned whether this geographic unit depends on intermittent immigration of lynx from Canada, and whether the historical lynx population cycles in Canada believed to have fueled such immigration are still occurring or will into the future. There doesn't appear to be much demographic input from recent cycles. There is evidence of lynx from this unit moving north into Canada, but little evidence of demographic interactions among the 3 subpopulations (Purcell Mountains, Seeley Lake, and Garnet Mountains) in this unit. Experts noted that the Garnet Mountains subpopulation at the southern end of this unit may have recently become extirpated (a single lynx was later [February, 2016] confirmed by DNA analysis in this area, suggesting the potential for natural recolonization of this range, but no other lynx were documented during winter 2016/2017).

Discussion among experts indicated that fire was more of a concern for this unit. Increased fire extent and severity or other catastrophic events and small subpopulation effects in separated mountain ranges could affect lynx persistence in the future in some parts of this unit. Fire exclusion in this area for the last 100 years likely resulted in the accumulation of fuels; however, this unit may have a reduced probability of a catastrophic fire over time because of recent changes in management and recent fires that may have reduced fuels. Out to the year 2050 and beyond, some experts felt there may be more pressure on lynx populations in this unit from continued increases in fire extent and severity. Other experts expressed a different opinion of the overall effect of fire in this unit, indicating that it may actually improve habitat over time, and

that whether fires improve or degrade habitat depends on the frequency, intensity, size and spatial extent of future fires.

Experts discussed the possibility for increased precipitation and warmer temperatures in this unit because of climate change, and how this might affect lynx habitats. Boreal/subalpine forest may move up in elevation as described above; however, experts expected a shift in forest composition and diminished lynx habitat quality in the future with climate change. It is unknown how much the distribution of dry ponderosa pine (non-habitat for lynx) will increase with climate change, but it is likely to happen at some level. One expert cautioned that some climate modelers estimated that vegetation will lag about 50 years behind the projected changes in temperature and precipitation. Snow levels in lower elevation areas are already decreasing in some areas, which could lead to smaller areas for lynx to use in winter in the future.

Taking all of these factors into consideration, experts provided “most likely” persistence probabilities of 95 to 100 percent (median = 98 percent) in the near-term (year 2025), 70 to 100 percent (median = 90 percent) at mid-century, and 50 to 90 percent (median = 78 percent) at the end of the century (fig. 12). As they did for most other geographic units, all experts indicated an initially high and subsequently decreasing likelihood that resident lynx will persist in this unit, with uncertainty increasing substantially over time.

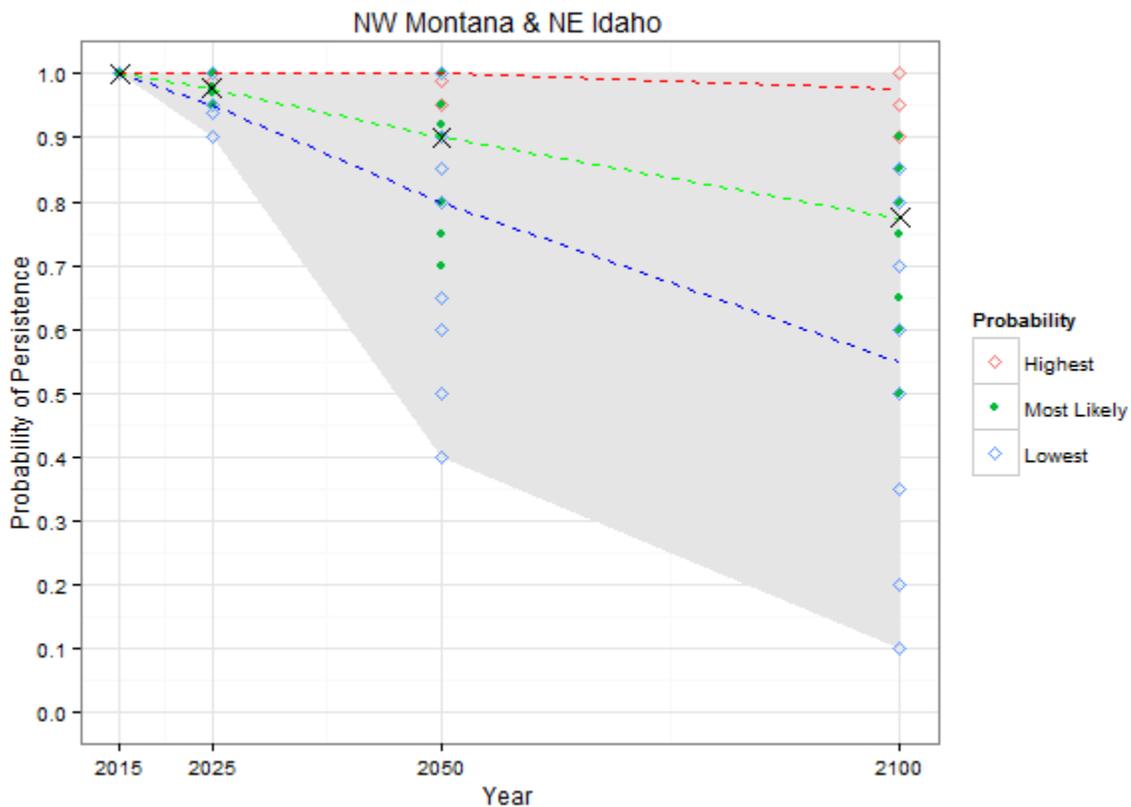


Figure 12. Lynx expert estimates of the probability that the Northwestern Montana/Northeastern Idaho Geographic Unit will continue to support resident lynx in the future (at years 2025, 2050, and 2100).

Service Evaluation of Factors Potentially Influencing Future Conditions

Regulatory Mechanisms - Federal, State, and Tribal regulations and land management direction could change in the future, but such changes and their potential impacts on lynx populations and habitats are difficult to predict. Because most (84 percent) of this geographic unit consists of Federal lands, the regulations and guidance that govern management of those lands have the greatest potential to influence future lynx habitats and populations in this unit. When Forest Service, Park Service, and BLM management plans are revised or amended, they require opportunities for public participation in accordance with several statutes (e.g., the National Environmental Policy Act [NEPA], National Forest Management Act [NFMA], National Parks and Recreation Act, Federal Land Policy and Management Act [FLPMA]; USFWS 2014 pp. 26-34, also see 3.1). If plan amendments or revisions may affect listed species, management agencies must consult with the Service in accordance with section 7 of the ESA. If in the future the lynx DPS is determined by the Service to no longer warrant listing under the ESA (i.e., if the DPS is removed from the *Federal Lists of Endangered and Threatened Wildlife and Plants*), the ESA requires the Service, in cooperation with the States, to monitor the DPS for a minimum of 5 years to assess its ability to sustain itself without the ESA's protective measures. If, within the designated monitoring period, threats to the DPS change or unforeseen events affect its stability, then the DPS could be relisted or the monitoring period extended. Given these requirements, we expect that future Federal management direction will continue to include regulations and guidance protective of lynx, although specific measures may change as new information becomes available.

We anticipate that future Federal management direction will include continued management of national parks, designated wilderness and roadless areas, and other areas with nondevelopmental land-use allocations to maintain natural ecological processes, which should maintain natural disturbance regimes and landscape-level habitat mosaics to which lynx are adapted (although continued climate warming [see below] may preclude maintenance of historical disturbance and landscape patterns). Regardless of the future listing status of the DPS, these lands will continue to be managed in accordance with the acts described above, as well as the National Park Service Organic Act and the Wilderness Act.

We also expect that Federal management into the future will include continued management of lands with developmental allocations to avoid or minimize potential impacts of vegetation management (timber harvest, thinning, salvage logging, other silvicultural prescriptions), wildland fire management (fire suppression, fuels reduction, prescribed fires), energy exploration and development, recreation, or other management activities with the potential to affect lynx. Current and likely future objectives include (1) managing vegetation to mimic or approximate natural disturbance and succession processes while maintaining habitat components necessary for lynx conservation; (2) providing a mosaic of habitat conditions through time that supports dense horizontal cover, high hare densities, and winter hare habitat in both young regenerating and mature multi-story forest stands; (3) using fire (natural and prescribed) to restore ecological process and maintain or improve lynx habitat, and (4) focusing vegetation management in areas with potential for improving winter hare habitat (BLM 2004a,

pp. 2-3; USFS 2007, Attachment 1, p. 2). Although specific standards and guidelines may change as new scientific information and management techniques become available, we anticipate continued Federal management designed to conserve or restore the capacity of the areas that historically or recently supported resident lynx populations, including the Northwestern Montana/Northeastern Idaho Geographic Unit, to continue to do so in the future.

On non-Federal lands (about 16 percent of this unit), as described above (sections 3.1.1 and 4.2.3, Habitat Status), recent acquisitions and conservation easements on some of the private lands in this unit will also reduce the likelihood of future adverse impacts to important lynx habitats. Similarly, the MTDNRC HCP includes a 50-year commitment to manage most (64 percent) State lands in this unit to conserve lynx foraging, denning, and connectivity habitats. Additionally, the Confederated Salish and Kootenai Tribe's objective to manage wildlife and habitats on the Flathead Reservation for future generations (section 3.1.2, Tribal Management) suggests continued management to conserve lynx habitats on Tribal lands.

Given the commitments and management objectives and practices described above, implementation of current and future regulatory mechanisms will likely continue to support conservation and restoration of lynx habitats in this unit and improve the likelihood that it will continue to support resident lynx into the future.

If the DPS was not listed, it is possible that State-managed trapping could resume in this and perhaps other geographic units. We expect that would only occur if scientific evidence strongly suggested the presence of a harvestable surplus of lynx and that harvest quotas would be carefully managed to ensure that the viability of resident lynx populations would not be diminished.

Climate Change - The recent evidence of climate change and the numerous mechanisms by which continued warming may affect future conditions for lynx and the potential consequences for the DPS and specific geographic areas are described in detail in section 3.2. Also, as noted above in section 4.2.3, evidence of warming and related impacts (increased temperatures, reduced snowpack, earlier snowmelt, and increased drought leading to increased fire) have already been documented in the Northern Rocky Mountains, including this geographic unit. Climate projections suggest these impacts are likely to continue and to result in future northward and upslope contractions of the snow conditions and boreal/subalpine vegetation communities that support lynx. This is expected to cause loss and increased fragmentation and isolation of lynx and hare habitats and, therefore, declining and more vulnerable lynx populations in the DPS and in this geographic unit (Carroll 2007, entire; Gonzalez *et al.* 2007, entire; ILBT 2013, pp. 69-71; 79 FR 54810-54811; Lawler and Wilsey *in* Lynx SSA Team 2016a, pp. 15-16; Siren *in* Lynx SSA Team 2016a, p. 15).

Snow conditions in this unit are projected to become less favorable, with an overall decrease in snowpack after mid-century as a result of a shorter snowfall season, fewer days with snowfall, and a lower proportion of winter precipitation in the form of snow (more as rain; Siren *in* Lynx SSA Team 2016a, p. 15). In this unit, the probability of snow conditions comparable to those

associated with historical lynx occurrence records is modeled to decline from 90-95 percent from 1961-1990 to 50 percent across much of the unit by the end of this century (years 2071-2100), although some parts of this unit are projected to retain favorable snow conditions (Gonzalez *et al.* 2007, pp. 12-14; Lynx SSA Team 2016a, pp. 15, 41). Tennant *et al.* (2015, pp. 2818-2820) simulated snowpack loss in the Northern Rockies (ID, MT, WY) and predicted that watersheds between 1,000 - 2,000 m (3,281 – 6,562 ft) elevation would experienced the greatest snowpack losses, while those > 2000 m (6,562 ft) would be more resilient to significant warming. Given the greater predicted snowpack persistence at some elevations used by lynx in this unit and the considerable area of potential climate refugia in mountainous terrain (Dobrowski 2011, pp. 1027-1029; Curtis *et al.* 2014, entire; Holden *et al.* 2015, entire; Morelli *et al.* 2016, entire), at least a portion of lynx distribution in this unit is likely resilient to climate-driven losses in snowpack (IDFG 2017a, p. 7).

There will likely be a lag time between the loss of favorable snow conditions and an eventual shift or contraction in vegetative communities (Lynx SSA Team 2016a, pp. 43, 59; also see section 3.2), but continued warming is projected to convert much of the boreal forest in this unit to temperate conifer forest by the end of the century (Gonzalez *et al.* 2007, pp. 15-17). The ability of lynx and hare populations to persist during this lag and to adjust to future habitat distributions is uncertain, but habitat quality, quantity, distribution, and connectivity are expected to decline, likely compromising this unit's future ability to support resident lynx populations.

Climate change has also been linked to increased wildfire size, frequency, and intensity in this geographic unit, and to increased frequency and extent of forest insect outbreaks in other parts of the DPS. These factors are likely to have temporary impacts on future lynx habitat, with regeneration to hare and lynx foraging habitat 20-40 years post-disturbance, depending on local climate, elevation, and topography. However, if extensive areas are affected, the ability of these landscapes to continue supporting resident lynx may be compromised, and lynx populations may be unable to persist until favorable vegetation conditions return. This is especially true where habitats and populations are naturally fragmented and patchily-distributed, and where landscape-level hare densities are already marginal, which appears to be the case for much if not all of this geographic unit.

Climate change has also been implicated in observed declines in the amplitude of northern hare and lynx population cycles (Yan *et al.* 2013, p. 3269). If lynx populations in this geographic unit are influenced (as is suspected) by intermittent immigration from the north, and if climate change diminishes the likelihood of future immigration via muted northern lynx population cycles, the future persistence of resident lynx in this unit is uncertain (see also Other Factors, below).

Given the factors described above, recent and projected future climate warming will likely reduce this geographic unit's ability to continue to support resident lynx into the future. The timing and magnitude of climate-driven impacts are uncertain; however, all are anticipated to adversely affect, and none are expected to benefit, lynx populations in this geographic unit. Climate model uncertainties and resolution limits, combined with our imperfect understanding of

historical and current lynx numbers and habitat distributions, preclude quantifying future habitat quality and distribution or lynx population dynamics in this unit. Nonetheless, it appears likely that continued climate warming will reduce future habitat quality and quantity and, therefore, the likelihood that this geographic unit will support resident lynx in the future.

Vegetation Management - Future vegetation management and, therefore, its implications for future lynx habitats and populations in this unit, are closely linked to the current and future regulatory mechanisms described above. As noted, we expect future vegetation management on all Federal and most non-Federal lands in this unit to continue to focus on maintaining and restoring lynx habitats by implementing standards, guidelines, and BMPs based on the best available scientific information. We expect these measures to continue to benefit lynx by limiting detrimental effects of timber harvest, thinning, fuels management, etc., and by encouraging the use of these activities to restore, improve, or create high-quality hare and lynx foraging habitats where feasible.

Wildland Fire Management - As noted in sections 3.4 and 4.2.3, past wildfire management, including fire suppression, does not appear to have altered the historical fire regime in lynx habitats in the western contiguous United States, including this geographic unit. Also as noted there and in sections 3.1.1 and the Regulatory Mechanisms section of this chapter, current Federal management restricts, with few exceptions, fire management (fuels reductions, prescribed fires, etc.) impacts to lynx habitats, and it promotes the use of such activities and wildfire response to conserve and restore lynx and hare habitats. We expect such conservation-focused fire management to continue and, therefore, to benefit lynx rather than to affect them detrimentally in the future.

However, as also noted in section 4.2.3, increased wildfire frequency, size, and intensity have been documented in this geographic unit, and that pattern is anticipated to continue in the future with continued climate warming. Although this increased wildfire activity does not appear to have diminished this unit's current ability to support resident lynx, it could do so in the future depending on the location, timing, and extent of future fires. As described in section 3.4, increases in fire frequency and size could rapidly convert large areas to the temporarily unsuitable stand-initiation successional stage, thus reducing the amount and altering the distribution of higher-quality habitats and potentially compromising this unit's ability to support a resident lynx population until burned habitats recover. Because lynx habitats are naturally patchily-distributed and landscape-level hare densities already marginal in many parts of this unit, it is possible that very large wildfires or many fires over a short time period could shift some parts of this unit from being just barely capable of supporting resident lynx to being incapable of doing so in the future. Although fire suppression was considered a potential risk factor for lynx in the DPS range, given the trends discussed above and the likely continued increase in future fire activity resulting from continued climate warming and drying, it may be necessary to reconsider whether fire suppression in some lynx habitats could benefit lynx by reducing the potential for extirpation of resident populations, especially in places already apparently only marginally capable of supporting them.

Habitat Loss/Fragmentation - As described above in section 4.2.3, lynx habitats in this unit are naturally fragmented but otherwise appear to be largely intact relative to historical conditions in most of this geographic unit. Although some localized impacts of past timber harvest and related activities have likely occurred, anthropogenic habitat loss or fragmentation does not appear to have broadly diminished this unit's ability to support resident lynx. Current and probable future management for conservation of lynx habitats suggests that broad-scale habitat loss or fragmentation resulting from timber harvest and other development activities are unlikely. The most likely sources of future habitat loss and fragmentation in this unit are the climate-mediated influences discussed above: increased wildfire activity and the projected contraction of vegetation and snow conditions favorable for lynx. Increased frequency, size, and severity of forest insect outbreaks, also driven by climate warming, has been documented in other geographic units and could occur in this unit in the future, too, resulting in temporary habitat loss and increased (though also temporary) fragmentation.

Additional highway construction and other transportation developments are likely in this unit, but the future locations, size, and potential impacts of such projects are difficult to predict. We are not currently aware of plans for specific major highway/road projects in this unit that would potentially impact lynx habitats and increase future habitat loss or fragmentation. Other potential sources of future habitat loss and fragmentation include recreation, minerals/energy development, and backcountry roads and trails; these are all considered second tier anthropogenic influences (ILBT 2013, pp. 78-85) that are unlikely to exert population-level influences, despite potential impacts to individual lynx.

Other Factors: Connectivity/immigration – As described above and in section 4.2.3, maintaining connectivity between this geographic unit and lynx populations in Canada is thought to be important, although it is uncertain if or to what degree immigration of lynx from Canada is essential to the persistence of lynx in this unit. A number of climate-mediated factors have been suggested as contributing to changes in the periodicity and amplitude of northern lynx and hare population cycles (see section 3.2), which could alter the timing and magnitude of lynx immigration into the contiguous United States from Canada. If lynx populations in this unit rely on immigration from Canada which is no longer occurring or has been substantially reduced relative to historical conditions, population declines and a reduced probability of persistence among resident populations would be expected.

Although the extent to which this factor may influence lynx populations in this unit is unknown, the population growth rate estimated for the Seeley Lake area ($\lambda = 0.92$, declining trend 1999-2007; Squires *in* Lynx SSA Team 2016a, p. 20) may reflect a gradual decline of a resident lynx population that needs but is not receiving adequate immigration. If this growth rate was applied continuously to a hypothetical resident population of 250 lynx (the midpoint of the range in the number of resident lynx this geographic unit may support based on expert opinion [Lynx SSA Team 2016a, p. 41]), the population would decline to 100 lynx after 11 years, about 50 lynx after 20 years, and roughly 20 individuals after 30 years. Vulnerability to demographic, environmental, and genetic stochasticity would increase as lynx numbers decreased, resulting eventually in an increased likelihood of functional extirpation of lynx from this unit (i.e., a lower

probability that the unit would continue to support a persistent resident lynx population). However, Schwartz (2017, p. 4) noted that very low immigration rates (less than 1 female/year on average for a theoretical population of 100 lynx) could provide population stability or even growth, suggesting that the Seeley Lake population and perhaps other DPS populations are probably being sustained by low levels of undetected immigration. Additionally, as noted above, the lynx population in the Purcell Mountains in the northwestern part of this unit was estimated to be increasing ($\lambda = 1.16$, 2003-2007; Squires *in* Lynx SSA Team 2016a, p. 20) over the last 4 years of the period for which the Seeley Lake population was estimated to be declining. In the absence of information on historic, recent, and likely future rates of immigration and its contribution to the persistence of lynx populations in this geographic unit, impacts of potentially reduced future immigration are difficult to project and are largely speculative at this time.

Conclusion

After reviewing the scientific literature and evaluating the factors that may influence lynx persistence in this unit, we concur with the experts' conclusion that this geographic unit is likely the most secure in the DPS. We conclude that it is very likely to continue to support resident lynx in the short term (through 2025) and through mid-century, although the number of lynx, the amount and distribution of high-quality habitat, and landscape-level hare densities are all likely to decline by mid-century as a result of continued climate warming and associated impacts. We also agree that this unit is more likely than not to support some resident lynx at the end of this century, although at that time we expect lynx numbers and distribution would be substantially reduced from the current condition and would, therefore, be more vulnerable to demographic, environmental, and genetic stochasticity and to catastrophic events, resulting in diminished resiliency. We acknowledge that under a *status quo* or increasing greenhouse gas emissions scenario the rate of climate-mediated loss, fragmentation, and isolation of habitat could, perhaps in concert with other factors (e.g., continued increases in wildfire size, frequency, and intensity and decrease in or complete loss of immigration from Canada), result in the functional extirpation of resident lynx from this unit before the end of the century. We also acknowledge, however, that there is great uncertainty with all persistence predictions that far into the future.

5.2.4 Unit 4 - North-central Washington

Expert Projections of Lynx Persistence

Compared to most other units, expert predicted a lower probability of persistence for this unit over the short term, and then a similar declining trajectory, with increasing uncertainty, by the end of the century, reflecting a more pessimistic outcome for this geographic unit than most other units (Lynx SSA Team 2016a, pp. 43-45). Experts felt that the probability of lynx persistence in this unit could decrease sharply over the next 10-20 years because of extensive recent fires in lynx habitats and the time needed for these areas to regenerate back to good hare/lynx habitat. However, 1 expert predicted an increase in persistence probability by mid-century as habitats impacted by recent large-scale fires regenerate into optimal hare-lynx

habitat. After that, the probability could rebound (or decline more slowly) over the longer term as these large areas return to prime habitat providing high hare densities.

Experts agreed that the current small population is likely at greater risk of extirpation because of stochastic events, particularly if large fires in lynx habitat continue to occur in the near future as they have in the recent past. A small population also could be more susceptible to disease, though no diseases have been documented among lynx in this unit. Experts discussed the extent to which small lynx populations could be reduced before they would become highly susceptible to stochastic demographic effects. It was suggested that 15-20 breeding individuals might be the minimum needed to avoid such susceptibility. Unimpeded connectivity between Canada and this unit could allow lynx to repopulate recently burned areas after the habitat recovers. Lynx in this unit are likely the southern portion of a larger population in Canada, not really a separate, isolated small population. Factors that influenced expert persistence probabilities for this unit included fire, habitat loss, and the future loss of favorable snow conditions predicted by climate change models.

Taking these factors into consideration, experts provided “most likely” persistence estimates of 60 to 95 percent (median = 80 percent) in the near-term (year 2025), 30 to 80 percent (median = 70 percent) at mid-century, and 5 to 50 percent (median = 38 percent) at the end of the century (fig. 13). Compared to most other geographic units, experts indicated greater uncertainty regarding short-and mid-term term persistence in this unit but, as for other units, uncertainty was greatest at the end of the century.

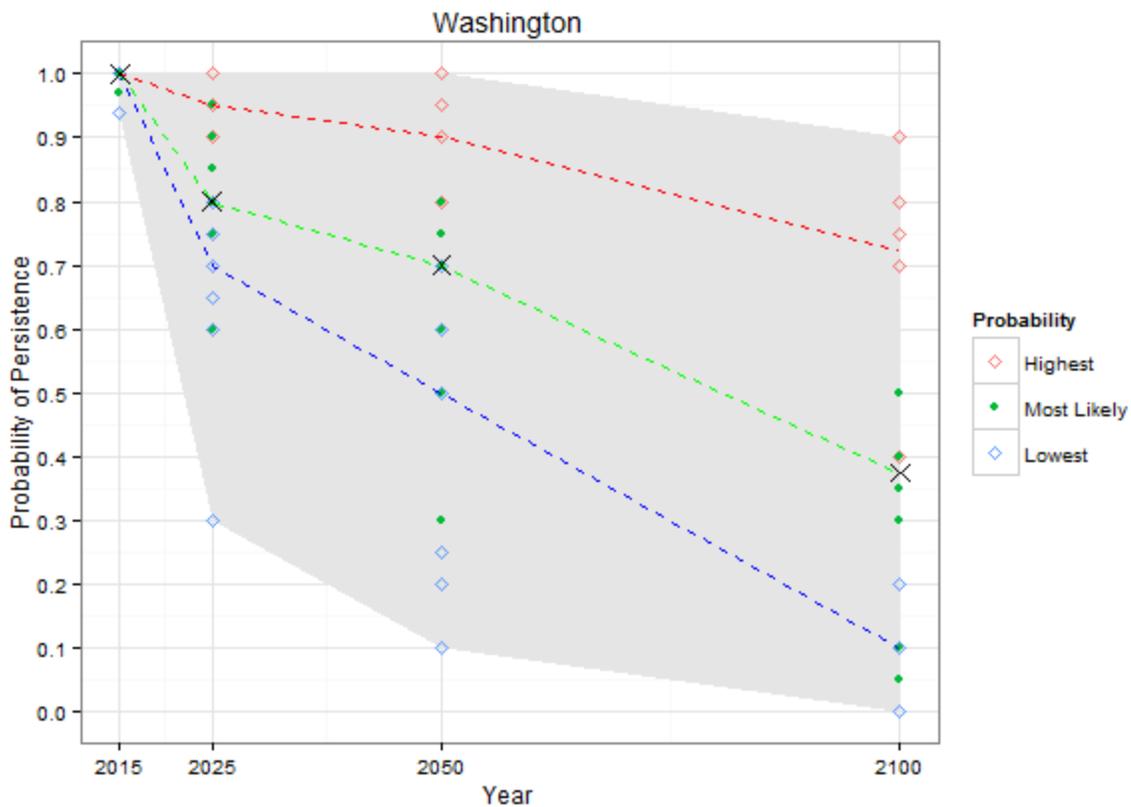


Figure 13. Lynx expert estimates of the probability that the North-central Washington Geographic Unit will continue to support resident lynx in the future (at years 2025, 2050, and 2100).

Service Evaluation of Factors Potentially Influencing Future Conditions

Regulatory Mechanisms - As described above (section 4.2.4), regulatory mechanisms currently in place guide forest management in this geographic unit for lynx conservation. We do not anticipate that existing regulatory protections for lynx would diminish appreciably in the future even if the DPS was no longer listed. On USFS lands, we anticipate that either the CA will remain in place (and/or be extended), or the OWNF and CNF will revise or amend their respective LRMPs to incorporate direction for lynx management similar to the formally amended LRMPs that have been implemented on all other national forests in the DPS range (see section 3.1.1). Currently, both the OWNF and CNF are in the process of amending or revising their LRMPs. We expect that management direction for lynx conservation addressing vegetation management, wildland fire management, and habitat fragmentation on National Forest System lands will be incorporated into the revised or amended LRMPs. We expect that both the OWNF and CNF will be required to manage for lynx and their habitat into the future because both forests will have incorporated lynx management direction into their respective LRMPs. We acknowledge that LRMPs can be amended or revised; however, LRMPs are typically in place for 15 years or longer, and the Service, other Federal and State agencies, and the public would have opportunities to comment on any proposed amendments or revisions to LRMPs through

the NEPA process. Therefore, we expect that both the OWNF and CNF will continue managing for lynx and their habitat into the future regardless of the DPS's listing status.

On State lands in this unit, the WADNR has committed to implementing its Lynx Habitat Management Plan until lynx are delisted or until 2076, whichever is shorter (WADNR 2006, p. 6). Additionally, the WADNR's internal policies encourage consideration of lynx habitat on lands it manages including participating in efforts to recover and restore endangered and threatened species, providing upland wildlife habitat, and establishing Riparian Management Zones. In accordance with legal obligations specified in the State's Forest Resource Plan, the WADNR will contribute to the future of Washington's lynx population by improving habitat conditions and reducing the likelihood of adverse effects on the habitat it manages (WADNR 2006, p. 6). Therefore, although some protections for lynx could be relaxed in the future if the DPS was not listed under the ESA, we anticipate that both Federal and State regulators would continue to manage for lynx conservation in this geographic unit.

Climate Change –Recent warming likely contributed to recent increases in wildfire activity in this unit and is likely to continue to do so in the future. Westerling *et al.* (2006, pp. 942-943) compiled information on large wildfires in the western United States from 1970-2004 and found that large wildfire activity has increased significantly from the mid-1980s with higher large-wildfire frequency, longer wildfire duration, and longer wildfire seasons. The greatest increases occurred in high elevation forest types including lodgepole pine and spruce fir in the northern Rockies (i.e., lynx habitat). They also found that fire exclusion (suppression) had little impact on natural fire regimes; rather, climate appeared to be the primary driver of increasing wildfire risk.

Koehler's (1990a, p. 847) estimated adult lynx density of 2.3 lynx/100 km² was obtained in an area supporting high-quality lynx habitat in the Meadows area of north central Washington (at least relative to other lynx habitat in Washington). Much of the lynx habitat in the Meadows was impacted by the recent large, stand replacing fires, resulting in further fragmentation of lynx habitat in the northern Cascades. Thus, the lynx densities Koehler observed in his study area may not be currently supported, because as habitat becomes more fragmented and isolated (i.e., marginal), the carrying capacity for a particular species declines.

As in other units, continued climate warming is projected to cause northward and upward shifts in spruce-fir habitats and snow conditions thought to favor lynx. In addition to potentially affecting fire return intervals, fire severity (intensity, size), and insect outbreaks, climate change is likely to affect the amount of precipitation falling as snow at elevations typically supporting lynx habitat in this geographic unit. Climate change is expected to impact the quantity, quality, and duration of snow in the Cascades. Mote (2003b, pp. 272, 274), who evaluated temperature trends in the Pacific Northwest using data collected by weather stations from 1930 to 1995, determined that the temperature increased in the Pacific Northwest and more precipitation fell in the spring and summer months, especially at elevations below 1,800 m (5,900 ft). Additionally, Mote (2003a, pp. 2-3) determined that an increasing temperature and precipitation trend from 1950 to 2000 is correlated with a 40 percent decrease in the snow water equivalent in the Cascades. Mote *et al.* (2005, p.45) determined that the Cascades are very sensitive to

temperature changes, with large increases in temperature potentially resulting in significant declines in snowpack. Corroborating Mote's results, Stoelinga *et al.* (2010, p. 2474) determined that the Cascade snowpack has declined by up to 40 percent in the latter half of the twentieth century, which resulted from increased temperatures. Furthermore, temperatures are predicted to continue increasing by 2° to 5°C (3.6° to 9°F) over the next century and are expected to cause further and accelerated losses in snowpack in the Cascades (Mote *et al.* 2005, p. 48). Continued declines of snowpack in the Cascades through 2025 are predicted to range from 9 percent (Stoelinga *et al.* 2010, p. 2486) to 29 percent (Elsner *et al.* 2010 *cited in* Stoelinga *et al.* 2010, p. 2486), which may also affect lynx densities supported in the Cascades.

Finally, some of the best lynx habitat in this geographic unit occurs on plateaus that may be more vulnerable to impacts of climate change because of the absence of higher elevation areas to which habitats and lynx could migrate in response to climate warming (Lynx SSA Team 2016a, p. 42). Thus, in addition to the recent losses of lynx habitat to large wildfires, coupled with increasing wildfire risk, the potential for the Cascades to support a viable lynx population may be further reduced because of projected climate-mediated decreases in snow quantity and quality. Overall, our review of the published literature on this subject leads the Core Team to conclude that climate change poses the greatest risk to the long-term persistence of lynx in this geographic unit.

Conclusion

After considering the best available scientific information and the opinions of lynx experts summarized above, the Core Team generally agrees with the experts that this geographic unit, like most others, has a relatively high likelihood of continuing to support a resident lynx population over the short-term (2025) and at mid-century (2050), but a lower probability of doing so, with more uncertainty, by the end of the century (2100). As described above, the potential effects of climate change on the quantity and quality of snow, as well as the projected northward and upslope movement of spruce-fir and subalpine fir forests are likely to result in further fragmentation and reduction of lynx habitat within this geographic unit by the end of the century. More fragmented and smaller habitat patches are likely to support a smaller and more isolated lynx population that will be more vulnerable to stochastic environmental and demographic events. Over the past 25 years, wildfires have reduced lynx habitat in this geographic unit by almost 40 percent and likely reduced its carrying capacity for lynx by a similar amount. Additional future losses of lynx habitat resulting from climate-driven increases in wildfire size, frequency, and intensity may pose the greatest near-term threat to the persistence of this population. Connectivity between this unit and Canada is likely to remain intact in the future. Because lynx are highly mobile and able to traverse large areas of non-lynx habitat, we do not anticipate that climate change, in and of itself, will significantly affect connectivity between this geographic unit and the larger lynx population in southern British Columbia. This connectivity may contribute to maintaining a persistent, albeit smaller, lynx breeding population in this geographic unit into the future.

5.2.5 Unit 5 - Greater Yellowstone Area

Expert Projections of Lynx Persistence

Current and future factors expressed by experts as influencing probability of persistence for this unit included small population size, forest disease and insect pests, and fire (Lynx SSA Team 2016a, pp. 45-46). Some experts doubt that the GYA unit currently supports a resident breeding population of lynx. Experts indicated that climate models predict that some parts of the GYA unit could provide refugia from climate change impacts because of their high elevations and potential to maintain winter snow levels into the future. Summer conditions in this unit, however, could be drier in the future, resulting in increased fire frequency, extent, and intensity, and additional temporary habitat loss. However, regeneration of these areas and the extensive areas that have burned in the recent past may provide good habitat over the next several decades. Some experts suggested that lynx emigrating to this unit from Colorado could occupy such improved habitats in the near future. Colorado lynx have made exploratory movements into the GYA in summer months, and analysis of available data could improve our understanding of Colorado lynx movement into and use of the GYA. It is possible that lynx from Colorado could maintain lynx in GYA.

Taking these factors into consideration, experts provided “most likely” persistence estimates of 10 to 70 percent (median = 52 percent) in the near-term (year 2025), 15 to 60 percent (median = 35 percent) at mid-century, and 5 to 50 percent (median = 15 percent) at the end of the century (2100; fig. 14). Unlike other units, the expert graphs for this unit were widely variable and had high uncertainty at all time frames. This was the only unit for which most experts believed the current probability of persistence is low (i.e., that it is uncertain whether this area currently supports a resident lynx population). Some experts increased persistence likelihoods into mid-century based on the possibility that large areas impacted by the 1980s-era wildfires may by then regenerate into hare/lynx habitat, and on possible continued dispersal of lynx from Colorado into this unit. Unlike other units, where expert confidence in their predictions was initially high but decreased greatly beyond mid-century, expert uncertainty in this unit was high for all time periods and was related to uncertainty about whether resident lynx currently occur in the GYA.

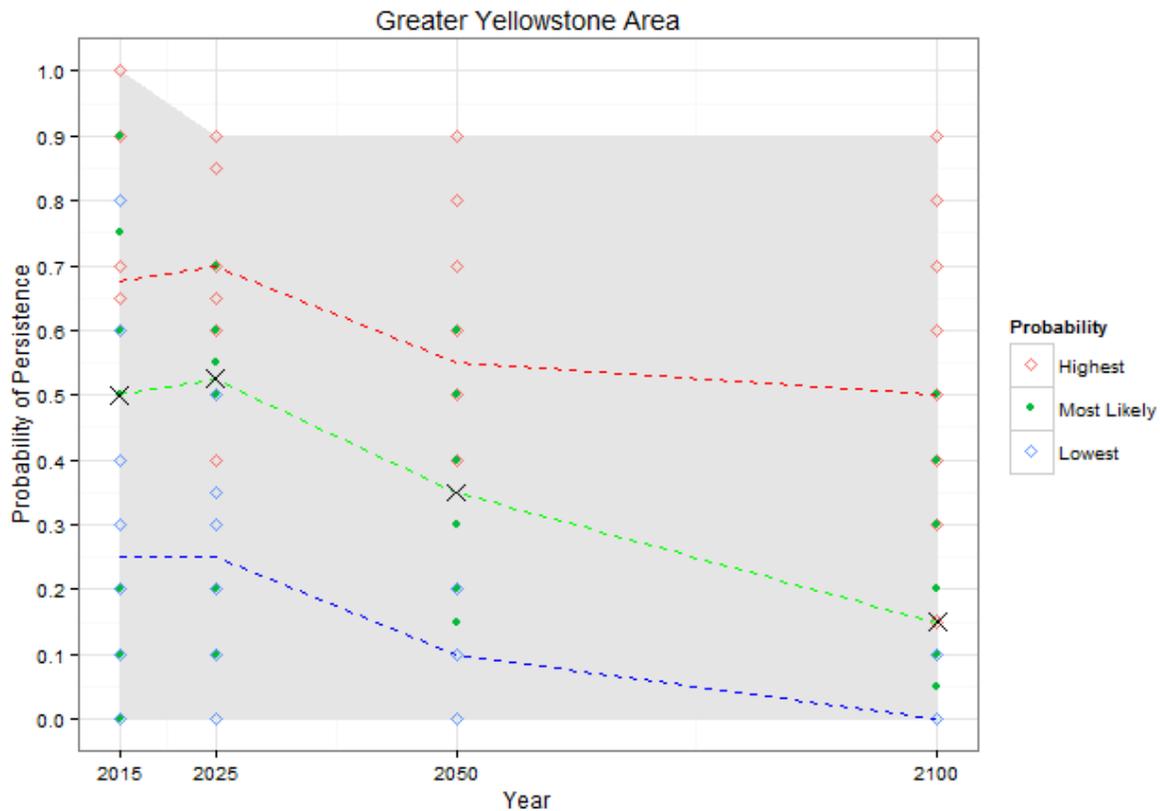


Figure 14. Lynx expert estimates of the probability that the Greater Yellowstone Area Geographic Unit will continue to support resident lynx in the future (at years 2025, 2050, and 2100).

Service Evaluation of Factors Potentially Influencing Future Conditions

Regulatory Mechanisms - As noted above in section 5.2.3, Federal, State, and Tribal regulations and land management direction could change in the future, but such changes and their potential impacts on lynx populations and habitats are difficult to predict. Federal lands account for over 97 percent of this geographic unit; therefore, regulations and guidance that govern management of those lands have the greatest potential to influence future lynx habitats and populations. Also as described above, revisions or amendments to Federal management plans require opportunities for public participation in accordance with NEPA, NFMA, National Parks and Recreation Act, and FLPMA (USFWS 2014 pp. 26-34; also see 3.1) and consultation with the Service in accordance with section 7 of the ESA. If the DPS is delisted in the future, the ESA requires a minimum of 5 years of monitoring to assess its ability to sustain itself without the ESA's protective measures. If, during that time, threats to the DPS change or unforeseen events affect its stability, then the DPS could be relisted or the monitoring period extended. Given these requirements, we expect that future Federal management direction will continue to include regulations and guidance protective of lynx, although specific measures may change as new information becomes available.

We anticipate that future Federal management direction will include continued management of national parks, designated wilderness and roadless areas, and other areas with nondevelopmental land-use allocations to maintain natural ecological processes, which should maintain natural disturbance regimes and landscape-level habitat mosaics to which lynx are adapted (although continued climate warming [see below] may preclude maintenance of historical disturbance and landscape patterns). Regardless of the future listing status of the DPS, these lands will continue to be managed in accordance with the acts described above, as well as the National Park Service Organic Act and the Wilderness Act.

We also expect that Federal management into the future will include continued management of lands with developmental allocations to avoid or minimize potential impacts of vegetation management (timber harvest, thinning, salvage logging, other silvicultural prescriptions), wildland fire management (fire suppression, fuels reduction, prescribed fires), energy exploration and development, recreation, or other management activities with the potential to affect lynx. Current and likely future objectives include (1) managing vegetation to mimic or approximate natural disturbance and succession processes while maintaining habitat components necessary for lynx conservation; (2) providing a mosaic of habitat conditions through time that supports dense horizontal cover, high hare densities, and winter hare habitat in both young regenerating and mature multi-story forest stands; (3) using fire (natural and prescribed) to restore ecological process and maintain or improve lynx habitat, and (4) focusing vegetation management in areas with potential for improving winter hare habitat (USFS 2007, Attachment 1, p. 2; BLM 2008, pp. A18-10 - A18-15; BLM 2010, pp. A-9 - A-12). Although specific standards and guidelines may change as new scientific information and management techniques become available, we anticipate continued Federal management designed to conserve or restore potential lynx habitats in this geographic unit in the future.

Given the commitments and management objectives and practices described above, implementation of current and future regulatory mechanisms will likely continue to support conservation and restoration of lynx habitats in this unit and improve the likelihood that it will support resident lynx into the future. Because non-Federal lands make up such a small proportion of this geographic unit, we believe it is unlikely that regulatory mechanisms on those lands will influence this unit's future ability to support resident lynx.

If the DPS was not listed, State-managed trapping could resume in this geographic unit, as elsewhere. We expect that would occur only if scientific evidence strongly suggested the presence of a harvestable surplus of lynx and that harvest quotas would be carefully managed to ensure that the viability of resident lynx populations would not be diminished.

Climate Change - The recent evidence of climate change and the numerous mechanisms by which continued warming may affect future conditions for lynx and the potential consequences for the DPS and specific geographic areas are described in detail in section 3.2. Also, as noted above in section 4.2.5, evidence of warming and related impacts (increased temperatures, reduced snowpack, earlier snowmelt, and increased drought leading to increased fire) have already been documented in the Northern Rocky Mountains, including this geographic unit.

Climate projections suggest these impacts are likely to continue and to result in future northward and upslope contractions in the snow conditions and boreal and subalpine vegetation communities that support lynx. This is expected to cause loss and increased fragmentation and isolation of lynx and hare habitats and, therefore, declining and more vulnerable lynx populations in the DPS and in this geographic unit (Carroll 2007, entire; Gonzalez *et al.* 2007, entire; ILBT 2013, pp. 69-71; 79 FR 54810-54811; Lawler and Wilsey *in* Lynx SSA Team 2016a, pp. 15-16; Siren *in* Lynx SSA Team 2016a, p. 15).

Snow conditions in this unit are projected to become less favorable, with an overall decrease in snowpack after mid-century as a result of a shorter snowfall season, fewer days with snowfall, and a lower proportion of winter precipitation in the form of snow (more as rain; Siren *in* Lynx SSA Team 2016a, p. 15). In this unit, the probability of suitable snow conditions is projected to decline from 90-95 percent from 1961-1990 to 50 percent across much of the unit by the end of this century (years 2071-2100), though some parts of this unit are projected to retain adequate snow (Gonzalez *et al.* 2007, pp. 12-14; Lynx SSA Team 2016a, pp. 15, 46). There will likely be a lag time between the loss of favorable snow conditions and an eventual shift or contraction in vegetative communities (Lynx SSA Team 2016a, pp. 43, 59; also see 3.2), but continued warming is projected to convert much of the boreal forest in this unit to temperate conifer forest by the end of the century (Gonzalez *et al.* 2007, pp. 15-17). The ability of lynx and hare populations to persist during this lag and to adjust to future habitat distributions is uncertain, but habitat quality, quantity, distribution, and connectivity are expected to decline, likely further compromising this unit's ability to support resident lynx populations, which is already questionable.

Climate change has also been linked to increased wildfire size, frequency, and intensity in this geographic unit, including the extensive fires in Yellowstone National Park in 1988, which burned over one-third of the park. Climate warming has also been linked to increased frequency and extent of forest insect outbreaks in other parts of the DPS. These factors are likely to have temporary impacts on lynx habitat, with regeneration to hare and lynx foraging habitat 20-40 years post-disturbance, depending on local climate, elevation, and topography. However, if extensive areas are affected, the ability of landscapes in the GYA to support resident lynx may be further compromised, and resident lynx may be unable to persist until favorable vegetation conditions return. This is especially true where potential habitats are naturally fragmented and patchily-distributed, and where landscape-level hare densities are already marginal, which appears to be the case for much of this geographic unit.

Climate change has also been implicated in observed declines in the amplitude of northern hare and lynx population cycles (Yan *et al.* 2013, p. 3269). If lynx populations in this geographic unit are influenced by intermittent immigration from the north, and if climate change diminishes the likelihood of future immigration via muted northern lynx population cycles, the future persistence of resident lynx in this unit is uncertain (see also Other Factors, below).

Given the factors described above, recent and projected future climate warming will likely further reduce this geographic unit's ability to support resident lynx into the future. The timing and

magnitude of climate-driven impacts are uncertain; however, all are anticipated to adversely affect, and none are expected to benefit, lynx and habitats in this geographic unit. Climate model uncertainties and resolution limits, combined with our imperfect understanding of historical and current lynx numbers and habitat distributions, preclude quantifying future habitat quality and distribution or lynx population dynamics in this unit. Nonetheless, it appears likely that continued climate warming will further reduce habitat quality and quantity and, therefore, the likelihood that this geographic unit will support resident lynx in the future.

Vegetation Management - Future vegetation management and, therefore, its implications for future lynx habitats and populations in this unit, are closely linked to the current and future regulatory mechanisms described above. As noted, we expect future vegetation management on all Federal lands in this unit to continue to focus on maintaining and restoring lynx habitats by implementing standards, guidelines, and BMPs based on the best available scientific information. We expect these measures to continue to benefit lynx by limiting detrimental effects of timber harvest, thinning, fuels management, etc., and encouraging the use of these activities to restore, improve, or create high-quality hare and lynx foraging habitats where feasible.

Wildland Fire Management - As noted in sections 3.4 and 4.2.5, past wildfire management, including fire suppression, does not appear to have altered the historical fire regime in lynx habitats in the western contiguous United States, including this geographic unit. Also as noted there and in sections 3.1.1 and the Regulatory Mechanisms section of this chapter, current Federal management restricts, with few exceptions, fire management (fuels reductions, prescribed fires, etc.) impacts to lynx habitats, and it promotes the use of such activities and wildfire response to conserve and restore lynx and hare habitats. We expect such conservation-focused fire management to continue and, therefore, to benefit lynx rather than to affect them detrimentally in the future.

However, as also noted in section 4.2.5, increased wildfire frequency, size, and intensity have been documented in this geographic unit, and that pattern is anticipated to continue in the future with continued climate warming. Although the extent to which increased wildfire activity has impacted this unit's current ability to support resident lynx is uncertain, such impacts may become more likely in the future depending on the timing and extent of future fires. As described in section 3.4, increases in fire frequency and size could rapidly convert large areas to the temporarily unsuitable stand-initiation successional stage, thus reducing the amount and altering the distribution of higher-quality habitats and potentially compromising this unit's ability to support resident lynx until burned habitats recover. Because lynx habitats are naturally patchily-distributed and landscape-level hare densities already marginal in many parts of this unit, it is possible that very large wildfires or many fires over a short time period could cause a shift in some parts of this unit from just barely capable of supporting resident lynx to incapable of doing so in the future. Although fire suppression was considered a potential risk factor for lynx in the DPS range, given the trends discussed above and the likely continued increase in future fire activity resulting from continued climate warming and drying, it may be necessary to reconsider whether fire suppression in some lynx habitats could benefit lynx by reducing the

potential for extirpation of resident populations, especially in places already apparently only marginally capable of supporting them.

Habitat Loss/Fragmentation - As described above in section 4.2.5, lynx habitats in this unit are naturally fragmented but otherwise appear to be largely intact relative to historical conditions in most of this geographic unit. Although some localized impacts of past timber harvest and related activities have likely occurred, anthropogenic habitat loss or fragmentation does not appear to have broadly diminished this unit's ability to support resident lynx. Current and probable future management for conservation of lynx habitats suggests that broad-scale habitat loss or fragmentation from timber harvest and other development activities are unlikely. The most likely sources of future habitat loss and fragmentation in this unit are the climate-mediated influences discussed above: increased wildfire activity and the projected contraction in vegetation and snow conditions favorable for lynx. Increased frequency, size, and severity of forest insect outbreaks, also driven by climate warming, has been documented in other geographic units and could occur in this unit in the future, too, resulting in temporary habitat loss and increased (though also temporary) fragmentation.

Additional highway construction and other transportation developments are likely in this unit, but the future locations, size, and potential impacts of such projects are difficult to predict. We are not currently aware of plans for specific major highway/road projects in this unit that would potentially impact lynx habitats and increase future habitat loss or fragmentation. Other potential sources of future habitat loss and fragmentation include recreation, minerals/energy development, and backcountry roads and trails; these are all considered second tier anthropogenic influences (ILBT 2013, pp. 78-85) that are unlikely to exert population-level influences, despite potential impacts to individual lynx.

Other Factors: Connectivity/immigration – This geographic unit is not directly connected to lynx populations in Canada or elsewhere in the DPS range, although lynx released into Colorado have dispersed northward into and through this unit. There is no reliable evidence of intermittent immigration into this unit during past irruptions of lynx from Canada, as has been documented in other parts of the contiguous United States, although anecdotal occurrence reports (see section 2.3.2.2) may suggest a pulse of immigrants in the early 1970s during the second of 2 unprecedented irruptions. Nonetheless, as elsewhere in the DPS, immigration may influence the persistence of resident lynx in this unit. If continued climate warming or other factors further reduce the chances that dispersing lynx will reach this unit and contribute to its demographic and genetic health, either through habitat loss and fragmentation in potential dispersal corridors or declines in the amplitude of northern hare and lynx population cycles, the likelihood that the unit will support resident lynx in the future may also decline. However, as in Unit 3 above, because we lack information of historic, recent, and likely future rates of immigration and its contribution to the persistence of lynx populations in this geographic unit, impacts of potentially reduced future immigration are difficult to project and are largely speculative at this time.

Conclusion

After reviewing the scientific literature and evaluating the factors that may influence lynx persistence in this unit, we concur with the experts' conclusion that this geographic unit is the least secure in the DPS. We find that conditions for lynx in this unit are naturally marginal, its historical or current ability to support a persistent resident lynx population are questionable, and continued climate warming and associated impacts are likely to further diminish its already limited ability to support resident lynx. We conclude that it may continue to occasionally or intermittently support a small number of resident lynx and some reproduction over the short term (through 2025), but that it is very unlikely to support a persistent resident population over that time frame, even less likely that it will do so at mid-century (2050), and highly improbable that this geographic unit will support resident lynx by the end-of-century (2100).

5.2.6 Unit 6 - Western Colorado

Expert Projections of Lynx Persistence

Some experts indicated that beetle kill and fire could potentially create poor habitat conditions in large areas of this unit by mid-century, but that forest regeneration after these impacts could result in good lynx/hare habitats. Others expressed uncertainty about whether fire and insect impacts would be temporary or permanent, especially considering climate change and the potential for conversion from boreal/subalpine forests to other forest types. Higher-quality lynx habitat in this unit occurs primarily in 2 areas and is patchily-distributed. Lynx in this unit may occur as several smaller, relatively isolated subpopulations, which are likely more vulnerable to stochastic events. This unit's relative isolation may limit exchange with other lynx populations, increasing the likelihood of genetic drift and reducing the chance of demographic rescue or recolonization if lynx in the unit become extirpated. There was discussion about whether ski areas may affect daily movements of lynx, and whether hares may be declining in ski areas. There is some evidence of lynx using ski areas in summer months but avoiding them during the ski season. Two-thirds to three-quarters of the lynx in this unit are in its southern portion in the San Juan Mountains. There is a large area (Weminuche Wilderness) that has not been well surveyed for lynx, so it is possible that lynx also could be using that area.

Taking these factors into consideration, experts provided "most likely" persistence estimates of 60 to 100 percent (median = 90 percent) in the near-term (year 2025), 50 to 85 percent (median = 80 percent) at mid-century (2050), and 20 to 70 percent (median = 50 percent) at the end of the century (2100; fig. 15). Most experts indicated an initially high and subsequently decreasing likelihood that resident lynx will persist in this unit, with uncertainty increasing substantially over time; however, experts also expressed substantial uncertainty over the near- and mid-term.

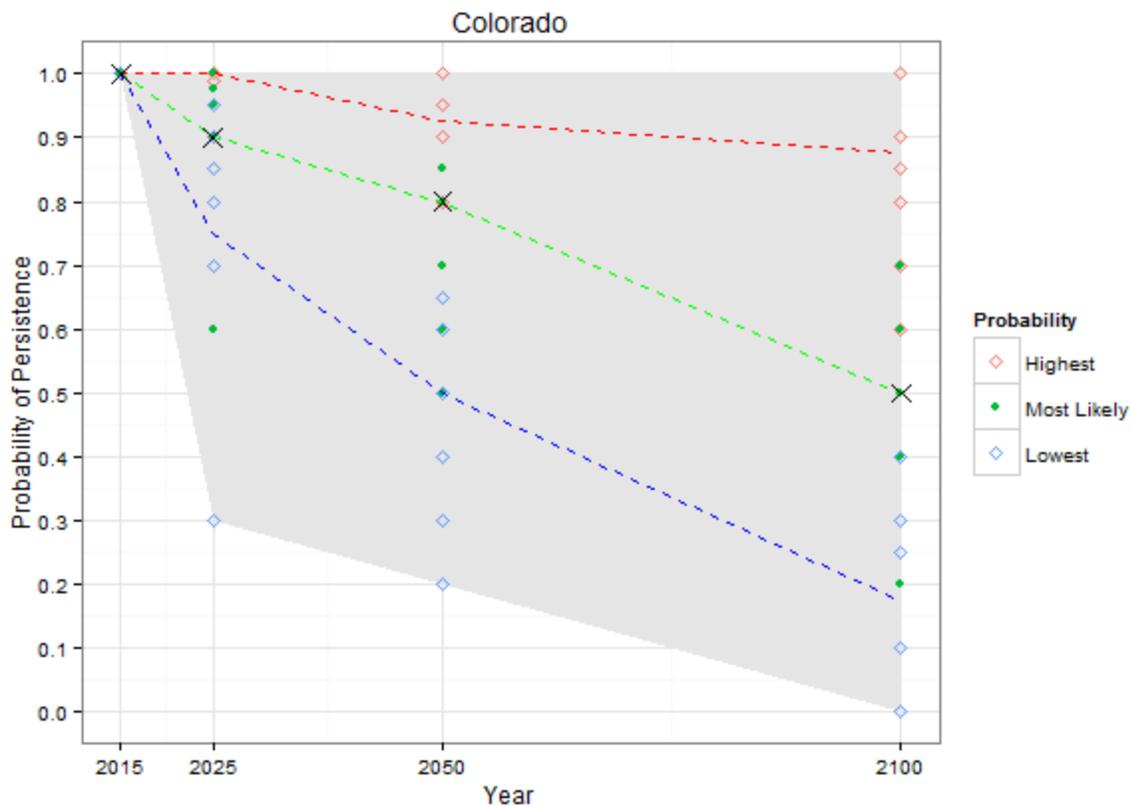


Figure 15. Expected probability of persistence for the Western Colorado Geographic Unit at present, 2015, and in 2025, 2050 and 2100.

Service Evaluation of Factors Potentially Influencing Future Conditions

Regulatory Mechanisms - Regulatory mechanisms for the conservation of lynx in the Southern Rockies consist of 7 amended USFS management plans in south-central Wyoming and Colorado. We concluded that the Southern Rockies Lynx Amendment substantively reduced the threat identified for previously inadequate regulatory mechanisms by addressing the major adverse impacts of Forest Service land management on lynx (USFWS 2008b, p. 70-71). Lynx habitat on all other ownerships makes up the remaining 15 percent of potential lynx habitat in Colorado, of which, only 5 percent is in Federal ownership. Other ownerships include state, county, municipal, etc., and private lands. Some BLM resource management plans have not been amended to include conservation specifically for lynx. Lynx habitat on BLM ownership mostly consists of narrow forest extensions connected to larger blocks of habitat on adjacent USFS lands. Generally these extensions are insufficient on their own to support a lynx home range. Additionally, the Gunnison Field Office is the only BLM unit that contains sufficient habitat to map and identify LAUs. The State of Colorado manages lynx as a State endangered species (C.R.S. 33-2-105), prohibiting take of the species with exceptions for protection of human life (C.R.S. 33-6-205) and incidentally during depredation management (not caused by lynx; C.R.S. 33-6-207).

Climate Change -In the Southern Rockies, warmer winters, earlier spring snowmelt, and a reduction in the extent of snow cover are expected consequences of climate change (ILBT 2013, p. 61). Using a variety of climate models, McKelvey *et al.* (2011, entire) predicted an overall 40 percent decline in persistent snow, but that snow would persist in large areas late in the 21st century, including the high elevations of Colorado.

“All of the climate models under all representative concentration pathways (RCPs) project that Colorado’s climate will warm substantially by 2050. Under RCP 4.5 (medium-low emissions scenario), Colorado’s annual temperatures are projected to warm by 1.4° to 2.8°C (2.5° to 5°F) by mid-century relative to the observed 1971–2000 baseline. Under RCP 8.5 (high emissions scenario), Colorado’s annual temperatures are projected to warm by 1.9° to 3.6°C (3.5° to 6.5°F) by mid-century. Summers are projected to warm slightly more than winters under both RCPs. Beyond mid-century, the warming trend is projected to continue into the late-21st century under all RCPs except RCP 2.6. By the period centered on 2070 (2055–2084), annual temperatures in Colorado are projected to warm under RCP 4.5 by 1.4° to 3.6°C (2.5° to 6.5°F) relative to the 1971–2000 baseline. Under RCP 8.5, the projected warming is 3.1° to 5.3°C (5.5° to 9.5°F) relative to the 1971–2000 baseline.” [Lukas *et al.* 2014, p. 61]

An analysis of projected 21st century temperature trends as a function of elevation in the Northern Hemisphere mid-latitudes from CMIP5 models shows more warming at higher elevations during winter, particularly in the daily minimum temperature (Rangwala *et al.* 2013 [cited in Lukas *et al.* 2014, p. 63]). “However, ..., the global climate models do not represent the topography of Colorado very well, so it is difficult to discern whether the warming projected for the higher elevation regions (> 10,000’) in the state is substantially different from that projected for lower elevations” (Lukas *et al.* 2014, p. 63).

On average, the climate models indicate a seasonal shift in precipitation for Colorado, with increasing winter precipitation, and in some areas a decrease in late spring precipitation (Lukas *et al.* 2014, p. 65). Although recent climate projections suggest that snow water equivalent (the amount of water held in a given amount of snow) may decline less in Colorado than in other areas of the Southwest, it is nonetheless projected to decline by 26 percent by the end of this century (Garfin *et al.* 2014, p. 466). This will likely translate to a reduction in the areas that will continue to have snow conditions that provide a competitive advantage to lynx over bobcats and other hare predators. Additionally, when specifically modeling potential impacts of climate change on lynx, researchers concluded that potential snow and boreal forest habitat refugia were most likely to occur in the Bridger-Teton National Forest in northwestern Wyoming, the Superior National Forest in northeastern Minnesota, and across western Canada, while high-elevation parts of Colorado are among the areas vulnerable to the loss of potential lynx habitat in the long term (Gonzalez *et al.* 2007, pp. 4, 8). Decker and Fink (2014, pp. 66-69) concluded that spruce-fir habitats in Colorado are only moderately vulnerable to the effects of climate change by mid-century under a moderate emissions scenario. Even if suitable snow conditions persist in Colorado and boreal and subalpine forests move upslope with continued climate warming, the amount of potential lynx habitat, already considered patchy and relatively isolated,

will likely decrease, becoming even more patchy and isolated and less capable of supporting lynx populations over time (79 FR 54794-54795).

We believe that continued climate warming will likely result in loss of favorable snow conditions, upslope migration of boreal forests, and increased frequency, size and intensity of wildfires and forest insect outbreaks in this geographic unit. We believe these factors will exacerbate the naturally highly-fragmented distribution of potential lynx habitat in this geographic unit and further diminish what already appear to be marginal hare densities in most of this unit. As a result, we expect this unit's ability to continue to support a resident lynx population will become more tenuous in the future than it is currently and likely was historically.

Vegetation Management - In the past decade, vegetation management within lynx habitat has been predominantly salvage of dead and dying timber caused by a mountain pine beetle infestation in the northern part of the state (generally north of Interstate 70), and a spruce bark beetle infestation south of the interstate. Salvage operations may temporarily impact understory regeneration, if present, reducing the capacity of the stand to support higher snowshoe hare densities. Assuming the existing USFS plans retain their current conservation framework, USFS lands should continue to provide sufficient habitat for lynx through the end of the century. Vegetation management on the small amount of non-Federal ownerships within lynx habitat is unlikely to cause significant concern for lynx conservation in Colorado through the remainder of the century.

Wildland Fire Management - "It is generally acknowledged that in the Southern Rocky Mountains fire suppression has altered historical vegetative patterns. This effect has been most pronounced within vegetation communities where fire regimes are of low intensity or mixed severity. It is generally agreed that spruce-fir habitats have been little affected by fire suppression because the fire regimes within this type tend to be stand-replacing events occurring at long intervals (100+ years). Depending on the moisture regime, large stand-replacing fires within lynx habitat may produce young age class snowshoe hare habitat after approximately 10-30 years. Although this vegetative condition may provide some high-quality snowshoe hare habitat, mature forests are also very important as winter foraging habitat." (USFS 2008b, p. 36).

Habitat Fragmentation - Sources of current habitat fragmentation include high-speed high-volume highways, high mountain valley developments, vegetation management, ski/recreation area development, and wildland fire. Currently, only vegetation management on USFS lands is managed to limit lynx habitat fragmentation. Highways are likely to be expanded to accommodate increasing traffic volume as mountain valley communities continue to develop and expand. While these linear features already exist on the landscape, widening of the cleared right-of-way, as well as lynx behavioral avoidance of highway rights-of-way because of increasing traffic volume reduces available habitat function for lynx. Many ski areas in Colorado are located within lynx habitat and will likely be expanded in the future through permanent removal of vegetation to create conventional ski runs, reducing tree density and clearing understory vegetation to create glade conditions, which reduces lynx habitat. The magnitude of

fragmentation caused by these sources has not been quantified, but is unlikely to remove enough lynx habitat to influence lynx persistence in Colorado.

Conclusion

Based on the best scientific information available, the Core Team is less optimistic than the expert panel about the future of lynx in western Colorado. Our uncertainty stems primarily from the historic record of lynx in Colorado, where evidence of lynx presence is questionable for much of the last century prior to CPW's reintroduction program. In addition, several demographic parameters of this new population (proportion of females that produce kittens and kitten survival), are very low compared to other units (1 and 3) where these parameters have been estimated based on adequate sample sizes. Further, the naturally limited and fragmented habitats and generally low hare densities, which were apparently incapable of supporting persistent resident populations historically, are likely to worsen with continued climate warming. This unit's greater distance and relative isolation from other lynx populations in the DPS and Canada, which may have prevented dispersing lynx from reaching this unit during the unprecedented irruptions from Canada into the northern contiguous United States in the early 1960s and early 1970s, also cast doubt on the likelihood that this unit will receive the demographic and genetic support from the north that is thought to be important to the maintenance of DPS populations. Because of these factors and uncertainties, we doubt that resident lynx will persist in this unit through the end of the century (2100), although we concur with experts that lynx will persist over the short-term (2025) and possibly until mid-century (2050).

We have considered the future of lynx in Colorado in the absence of the protections offered by the ESA. We believe that as long as the current regulatory mechanisms provided by the State of Colorado to prevent take of lynx and the USFS SRLA conservation framework remains in place, lynx are likely protected from take, and their habitat requirements likely met in a significant majority of the potential habitat within the state. Projected future climate warming is likely to result in reduction of available habitat and increased fragmentation resulting in larger areas of non-habitat between habitat blocks. Vegetative changes caused by climate change will likely reduce the amount of habitat in private and BLM ownership due to the anticipated upslope shift in vegetation that supports snowshoe hares and lynx.

The movement capability of lynx is well documented, and lynx in Colorado will likely continue to exploit the available habitat despite gaps between functional habitat blocks. Colorado is isolated from source populations in the northern part of the range relative to the other units, which likely increases the possibility of genetic drift in this unit. Expert elicitation revealed some uncertainty whether ski areas or other development may affect connectivity within the unit. However, the Core Team is less concerned about this particular issue because we cannot foresee the development of barriers that would prevent lynx from accessing available lynx habitat in the future.

Chapter 6: Synthesis

This section synthesizes the needs, current condition, and likely future condition of the Canada lynx in the contiguous United States DPS with respect to the conservation biology principles of representation, redundancy, and resiliency. Its purpose is to provide an understanding of the range-wide status of the DPS that is as clear as possible given irresolvable uncertainties regarding historical distribution and population sizes, as well as uncertainty about current population sizes and trends, other key demographic information (e.g., immigration and recruitment rates and their influence on population stability/persistence), and the timing and magnitude of projected climate-mediated impacts and other long-term stressors.

Species' Needs

Throughout its range, the Canada lynx is a habitat and prey specialist requiring large (hundreds to thousands of square kilometers) boreal forest landscapes with dense horizontal cover and robust populations of its primary prey, the snowshoe hare. Resident lynx populations are generally restricted to areas with abundant hares and long (4+ months) winters with deep, persistent snow, which is believed to confer lynx a seasonal competitive advantage over other terrestrial predators of hares. Lynx in the contiguous United States have ecological requirements similar to those of lynx in Canada and Alaska, and throughout the species' range hare abundance is the primary driver of lynx population dynamics. Recent research in the DPS range supports the hypothesis that hare densities consistently near or above 0.5 hares/ha (0.2 hares/ac) are necessary to support persistent resident lynx populations (see section 2.2.1). However, the DPS is at the southernmost margin of the species' range, where boreal forests transition to temperate conifer and hardwood forests, and where hare abundance and snow conditions generally become less favorable with decreasing latitude. Because of this, habitat is naturally less extensive and generally more fragmented within the DPS range than in the core of the species' range in Canada and Alaska. As a result, lynx in much of the DPS range are naturally less abundant and more patchily-distributed than in the core of the species' range (except during decadal lows in hare population cycles, when both hares and lynx occur temporarily in the north at densities lower than most in the range of the DPS). Maintaining connectivity with lynx populations in Canada is thought to be important to the persistence of DPS populations; however, whether, and if so to what extent, the demographic and/or genetic health of DPS populations relies on periodic immigration from Canadian populations remains uncertain.

Current Conditions and Threats

Resiliency, the ability to withstand stochastic disturbance events, and redundancy, the ability to withstand catastrophic events, are currently exhibited in the lynx DPS by the persistence of individual lynx populations and their broad distribution across the geographic scope of the DPS. Available information indicates that 5 out of 6 geographic units in the DPS (all but the GYA) currently contain resident breeding lynx populations. Although we lack precise historical and

current population-size estimates for all of the geographic units, lynx experts familiar with each unit provided their estimates of the number of resident lynx each unit could potentially support.

- Northern Maine (Unit 1) – This unit has likely supported resident lynx since at least the southward re-expansion of boreal spruce-fir forests into the northeastern United States during and following the Little Ice Age (see section 3.2). Currently, northern Maine is thought to support many more resident lynx than likely occurred historically, and many more than was known or suspected at the time the DPS was listed. This unit currently contains an unnaturally-high amount of high-quality hare habitat; the result of dense conifer regeneration following landscape-level clearcutting in the 1970s and 1980s in response to a large spruce budworm outbreak. These dense young regenerating conifer stands are much more extensive than they are thought to have been historically under natural disturbance regimes. However, habitat extent probably peaked in the late 1990s and early 2000s, and habitat quality is projected to decline in these stands over the next few decades as they age beyond 35-40 years post-harvest. This unit currently is thought to support the largest resident population in the DPS; perhaps 750-1,000 individual lynx (Vashon *in* Lynx SSA Team 2016a, p. 18). This geographic unit may also be the source of dispersing lynx that recently recolonized northern New Hampshire as well as several that temporarily established residency in northern Vermont. Some reproduction has been verified recently in both states, although neither was occupied when the DPS was listed, and resident lynx were thought to have been extirpated from New Hampshire.
- Northeastern Minnesota (Unit 2) – This unit supports many more resident lynx than was suspected when the DPS was listed, although how the current population compares to historical conditions is uncertain. When the DPS was listed, it was uncertain whether this unit supported any resident lynx or if historic records were of dispersing lynx associated with cyclic irruptions from Canada. Trapping records indicate strongly cyclic increases in lynx abundance in this unit in the 1930s through 1970s in association with decadal irruptions of lynx dispersing south from Canada. This unit currently supports a resident lynx population thought to number from 50-200 (Moen *in* Lynx SSA Team 2016a, p. 19). There is no information to suggest that this unit historically supported a larger resident population or a more extensive distribution of habitat capable of doing so.
- Northwestern Montana and Northeastern Idaho (Unit 3) – Recent research, monitoring, and habitat mapping refinements indicate that habitats capable of supporting resident lynx in this and other western geographic units are naturally less abundant and more patchily-distributed than was thought when the DPS was listed. For example, earlier estimates that western Montana supported 1,000 or more lynx were based on broad assumptions regarding habitat suitability and lynx distribution that are not supported by current understanding of lynx habitat requirements (see section 4.2.3). Currently, this unit is thought to be capable of supporting 200-300 resident lynx. How the current population compares to historical conditions is uncertain, but we find no evidence that this unit historically supported a larger resident population or a substantially broader distribution of habitat capable of doing so. Lynx habitats in this unit are naturally patchy

and fragmented due to topography and elevational and moisture (aspect) constraints. Wildfires have burned over 5,200 km² (2,008 mi²; nearly 20 percent of the unit) of forest in this unit since 2000, although the amount that occurred in lynx habitat is uncertain. During the 2017 fire season alone, roughly 1,150 km² (444 mi²; over 4 percent of the unit) burned, including the Rice Ridge and Reef fires, which together burned over 690 km² (267 mi²) in the core of the Seeley Lake population's habitat²⁷. Population-level impacts of these fires have not yet been demonstrated.

- North-central Washington (Unit 4) – Extensive wildfires over the past several decades have (probably temporarily) reduced the amount of high-quality lynx habitat and have likely caused a decline in lynx carrying capacity in this unit from perhaps 50 lynx (based on this unit's proportional contribution to the larger Okanogan LMZ) before the large fires to roughly 30 lynx currently (Lewis 2016, pp. 4-6). The Diamond Creek wildfire burned another large block of lynx habitat in the northern part of this unit in 2017. Because of this, the current number of resident lynx in this unit is likely lower than it was historically and when the DPS was listed. Additional fires in this unit before previously burned areas recover (10-40 years post-burn) would further reduce lynx numbers and make this geographic unit more vulnerable to extirpation. Because of these habitat impacts and remaining stressors to lynx, the Washington Department of Fish and Wildlife recently submitted, and the State Fish and Wildlife Commission adopted, a proposal to uplist lynx from threatened to endangered within the State.
- The Greater Yellowstone Area (GYA, Unit 5) – Based on evaluation of verified historic records, it is uncertain whether this geographic unit historically supported a small but persistent resident population or supported resident lynx only ephemerally. There are very few verified lynx records in the GYA from 1920-1999, but several resident lynx and evidence of reproduction were verified in the late 1990s and early 2000s (around the time the DPS was listed). In addition, at least 9 radio-marked lynx released in Colorado (see below) dispersed northward into or through this unit from 2003-2010, but no lynx have been detected in the GYA since 2010. Most places surveyed in Yellowstone National Park had hare densities clearly too low to support resident lynx. However, parts of the Wyoming Range south of the park, where many historical and most recent occurrences in this unit have been concentrated, had hare densities among the highest documented in the DPS range. No population estimates are available, but expert opinion suggests that this unit may only support 0-10 lynx, and we find no reliable evidence that it once supported a larger or persistent resident population.
- Western Colorado (Unit 6) – There currently are many more resident lynx in this unit than likely occurred historically, and many more than were known or suspected at the time the DPS was listed. There were even fewer verified records in this unit during the last century than in the GYA, and no reliable evidence of a resident breeding population. However, from 1999-2006, 218 Canadian and Alaskan lynx were released into the San

²⁷ <https://inciweb.nwccg.gov/state/27/0/>

Juan Mountains of southwestern Colorado. As a result of the subsequent reproduction of some of the released lynx and some of their offspring over several generations, resident lynx currently occupy this unit. When the DPS was listed in 2000, 27 of 41 lynx released in 1999 were still alive. The State of Colorado has concluded that its efforts have established a viable lynx population, and the State's lynx experts suggest this unit may currently support 100-250 resident lynx (Ivan *in* Lynx SSA Team 2016a, p. 47). Recent snow-tracking and camera surveys in the San Juan Mountains in the southern part of the unit documented evidence of continued lynx residency and reproduction.

The apparent long-term (historical and current) persistence of resident lynx populations in at least 4 of the 6 geographic units (Units 1-4) and the absence of reliable information indicating that the current distribution and relative abundance of resident lynx are substantially reduced from historical conditions suggest the historical and recent resiliency of lynx populations in the DPS. The current resident population in Unit 6 has also demonstrated resiliency thus far. The large sizes and broad geographic distributions of the areas occupied by resident lynx populations likewise indicate historical and current redundancy in the DPS sufficient to preclude the possibility of extirpation from catastrophic events.

Representation, the ability of a species to adapt to changing environmental conditions over time, is characterized by the breadth of genetic and ecological diversity within and among populations (Lynx SSA Team 2016a, p. 25). Information provided by lynx experts and geneticists indicates high rates of dispersal and gene flow and, therefore, generally low levels of genetic differentiation across most of the species' range, including the DPS (Lynx SSA Team 2016a, pp. 12-14, 55-56). Hybridization with bobcats has been documented but is not considered a substantial current threat to the DPS (Lynx SSA Team 2016a, p. 13). Despite differences in forest community types and topographic/elevation settings, lynx across the range of the DPS occupy a similarly narrow and specialized ecological niche defined by specific vegetation structure, snow conditions, and the abundance of a single prey species. Thus, lynx naturally have little ability to adapt to changing environmental conditions (i.e., shift to other forest habitats, snow conditions, or prey species). However, although some small populations may have become extirpated recently, resident lynx in the DPS remain broadly distributed across the range of ecological settings that seems to have supported them historically in the contiguous United States. There are no indications of current threats to the genetic health or adaptive capacity of lynx populations in the DPS, and the current level of representation does not appear to represent a decrease from historical conditions.

The lack of regulations protecting lynx habitat from potential threats on Federal lands at the time of listing has been largely addressed by formal and binding amendments or revisions to most Federal land management plans within the DPS range. Although uncertainty remains about the efficacy of this improved regulatory framework, Federal lands are now being managed specifically to protect and restore lynx habitats, with the goal of supporting continued lynx presence on these lands. Most Federal lands, which constitute 64 percent of lynx habitat evaluated in this SSA, are found in the western United States.

Climate change is occurring at a global and, thus, a DPS-wide scale. Climate warming has reduced snow amount, duration, and quality (in terms of conditions thought to be favorable for lynx); it has been linked to increased frequency, size, and severity of wildfires and forest insect outbreaks; and it likely has already resulted in some changes in forest vegetative communities. Climate warming has also been suggested as contributing to changes in the amplitude, periodicity, and synchronicity of northern hare population cycles, which could alter (and perhaps have already altered) the timing and magnitude of lynx dispersal from Canada into the contiguous United States. If lynx populations in the DPS depend on immigration from Canada which is no longer occurring or has been reduced substantially relative to historical conditions, population declines and an increased likelihood of extirpation among resident DPS populations would be expected. However, whether, and if so to what extent, these climate-mediated factors have influenced current lynx numbers, other demographic parameters, and/or habitat quality and distribution is uncertain and has not been quantified across the range of the DPS or in individual geographic units. Despite uncertainty regarding its influence over current conditions for lynx, climate modeling and expert opinion concur that continued climate warming will adversely impact lynx in the DPS at some point in the future (also see *Future Conditions and Threats*, below).

There are other current stressors that are not occurring across the entire DPS range but which affect lynx in 1 or more geographic units. For example, in northern Maine, where most high-quality lynx habitat occurs on private commercial timber lands and is the result of past timber harvest, changes in State forestry regulations (the Maine Forest Practices Act of 1989) that govern private forest management may currently be facilitating decreases in habitat quantity, quality, and distribution, and may result in reduced lynx numbers (also see *Future Conditions and Threats*, below). The lack of binding lynx conservation commitments on most private lands may exacerbate this risk to current lynx habitats in Maine. However, the current amount and distribution of high-quality lynx and hare habitats created in Maine by past timber harvest is thought to be several times higher than the likely natural historical condition. In North-central Washington, recent large-scale wildfires have resulted in the temporary loss of over a third of lynx habitat, likely reducing this unit's current lynx population and potentially compromising its current ability to support a resident population until habitats recover. Increased wildfire activity also has impacted lynx habitats in the other western geographic units (Northwestern Montana/Northeastern Idaho, the GYA, and Western Colorado), but the extent to which it may have influenced the current condition of lynx populations in those units is uncertain.

Future Conditions and Threats

In our future condition analysis, including expert elicitation, we considered three time periods (2025, 2050, and 2100), with greater uncertainty in predicting effects to lynx and lynx habitat the further out we look into the future. Compared to the other time periods, predictions out to 2100 are complicated by considerably higher uncertainty. Overall, our evaluations of the scientific literature and expert input suggest that resident lynx populations in each of the geographic units are likely to be smaller and their distributions reduced in the future. These anticipated declines are most likely to be influenced by projected loss and increasing fragmentation and isolation of

boreal forests and favorable snow conditions resulting from continued climate warming and related impacts (e.g., increased wildfire and forest insect activity, diminished hare populations; Lynx SSA Team 2016a, p. 58). Forest management on private lands that lack lynx conservation commitments may also contribute to future declines, particularly in northern Maine. In each geographic unit, the probability that resident lynx populations will persist is expected to decline through the end of the century, with uncertainty about the rate of decline increasing with time from the present. The loss of resident lynx from 1 or more geographic unit would represent reduced future resiliency, redundancy, and representation within the lynx DPS.

The resiliency of lynx populations in individual geographic units is the primary determinant of the future viability of the lynx DPS. Our analyses and expert predictions suggest a declining probability of persistence (loss of resiliency) for each of the geographic units within the DPS throughout the rest of this century (the analysis did not extend beyond 2100). Projected climate warming is expected to exert the greatest influence on the resiliency of individual populations, and thus continued presence of resident lynx in each geographic unit. Climate models project that boreal forests and snow conditions favorable for lynx at the southern periphery of the range will retreat northward and upslope with continued warming, further fragmenting and diminishing the quality of lynx and hare habitat within the DPS. Although uncertainty remains regarding the timing, extent, and biological consequences of such impacts, as habitat conditions decline, hare populations are also likely to decline and lynx mortality rates are likely to increase and reproductive rates decrease. As snow conditions become less favorable, other terrestrial hare predators (e.g., bobcats and coyotes) may outcompete and displace lynx. This in turn would reduce lynx abundance and density within populations, making populations more susceptible to stochastic events.

Here we present future condition analysis summaries for each geographic unit (also see table 1 and figure 2):

- Northern Maine (Unit 1) – We concur with the expert panel that the resident lynx population in this unit is very likely to persist at 2025 and at 2050. Over the longer-term (at 2100), we expect continued climate warming to reduce the amount and quality of lynx habitat in this unit and exacerbate other potential stressors (commercial and energy developments, changing forestry practices and land ownership patterns, etc.), further reducing lynx numbers and decreasing the population’s resiliency. Some climate models indicate substantial loss of boreal forest and favorable snow conditions under higher emissions scenarios, and this unit generally lacks potential elevational refugia that would support upslope movement of lynx habitats and populations. Therefore, we suggest that the likelihood that this unit will support a resident lynx population at 2100 may be somewhat lower than expert projections, although the timing and extent of future climate-mediated habitat decline is highly uncertain.
- Northeastern Minnesota (Unit 2) – We concur with the expert panel that the resident lynx population in this unit is very likely to persist at 2025 and at 2050. Over the longer-term (at 2100), we expect continued climate warming to reduce the amount and quality of lynx

habitat in this unit, likely reducing lynx numbers and decreasing the population's resilience. Under higher emissions scenarios, some climate models project substantial loss of boreal forest and favorable snow conditions in this unit before the end of the century. Like Maine, this unit also lacks potential elevational refugia that would support upslope movement of lynx habitats and populations. Therefore, we suggest that the likelihood that resident lynx will persist in this unit at 2100 may be somewhat lower than expert projections, although the timing and extent of climate-mediated habitat decline is highly uncertain.

- Northwestern Montana and Northeastern Idaho (Unit 3) – We concur with the expert panel that resident lynx are very likely to persist in this unit at years 2025 and 2050, and likely to do so at 2100. Over the longer-term, we expect continued climate warming and associated impacts, perhaps especially increased wildfire activity, to reduce the amount and quality of lynx habitat in this unit, reducing lynx numbers and likely decreasing the population's resilience. Although the timing and extent of climate-mediated habitat decline is highly uncertain and fire-driven habitat loss typically would be temporary, wildfire size, frequency, and intensity have increased in this unit over the past few decades, and this pattern is expected to continue with projected climate warming.
- North-central Washington (Unit 4) – We concur with the expert panel that the resident lynx population in this unit is very likely to persist at years 2025 and 2050. Over the longer-term (2100), we expect continued climate warming to reduce the amount and quality of lynx habitat in this unit, further reducing lynx numbers and likely decreasing the population's resilience. Therefore, we concur with experts that this unit has a relatively lower likelihood of supporting a resident population at 2100, although the timing and extent of climate-mediated habitat decline is highly uncertain.
- The Greater Yellowstone Area (GYA, Unit 5) – Given the uncertainty whether this unit historically or recently supported a persistent resident population and the lack of evidence that it is currently occupied by resident lynx, we concur with experts that it is very unlikely to support a resident population in the future.
- Western Colorado (Unit 6) – We concur with the expert panel that resident lynx in this unit are likely to persist at year 2025. However, given this unit's apparent historical inability to support a persistent resident population, its relative isolation from other lynx populations, its naturally fragmented habitat and generally very low hare densities, and its generally lower proportion of females producing kittens and low kitten survival, we believe it is less likely than expert projections to support a resident population at 2050 or at 2100. It is possible that hare densities will increase over the next several decades as large areas of forest regenerate from recent extensive insect and fire impacts. However, we expect any increase in hares to be temporary and accompanied by a longer-term insect- and fire-driven decrease in red squirrel (an important alternate prey species in this unit) abundance.

The loss of resident lynx populations in any geographic units would also reduce the level of redundancy and could diminish representation within the DPS. With regard to redundancy, however, we find that none of the 5 geographic units that currently support resident lynx is vulnerable to extirpation from a single catastrophic event. Given that, we conclude that the DPS as a whole is not vulnerable to extirpation from a catastrophic event. We recognize that a sequence of discrete but spatially-clustered catastrophic events in lynx habitats over a short time could increase the potential for functional extirpation in 1 or more of the individual geographic units (especially the possibility of additional large wildfires in north-central Washington), thereby reducing redundancy within the DPS. However, as long as resident lynx remain geographically well-distributed in 1 or more units within the DPS, extirpation of the DPS from a single catastrophic event is very unlikely.

With regard to representation, although some lynx populations in the DPS units are demographically isolated from each other and the level of interaction between others is uncertain, there seems to be little risk of significant genetic drift. This is because of the currently-observed and likely future high level of gene flow across most of the lynx's continental range, the species' well-documented dispersal capability, the current and likely future absence of significant barriers to dispersal between Canada and the DPS, and continued connectivity between most parts of the DPS and lynx populations in Canada. Furthermore, based on expert input, we conclude that there is no indication that the relatively low level of genetic diversity currently observed among lynx populations is likely to reduce DPS viability in the future (Lynx SSA Team 2016a, p. 51). This information suggests the current and likely future relative genetic health of the DPS. However, the potential for genetic drift would be expected to increase at some point in the future if lynx and hare habitats shift northward and upslope, as projected with continued climate warming, resulting in reduced connectivity and gene flow among smaller and more isolated lynx populations at the periphery of the range (Schwartz 2017, pp. 4-5; also see section 3.2).

How the potential loss of resident lynx from 1 or more geographic units may affect representation within the DPS in terms of ecological diversity is uncertain. Despite similarities in the fundamental components (vegetation, snow conditions, and hares) that define the ecological niche of lynx DPS-wide, differences in habitats and how lynx use them are apparent. For example, snow depth that seems to demarcate a boundary between lynx and bobcat occupancy in Maine (270 cm/yr [106 in/yr]) is almost twice that observed in Minnesota (140 cm/yr [55 in/yr]), and lynx in some parts of the West select mature forest stands, particularly in winter, while in other parts of the DPS, young regenerating stands are most important. The loss of resident lynx from any of the geographic units could result in the loss of behavioral and potential future genetic adaptations to the climate-mediated changes now occurring and likely to continue into the future at the southern edge of the lynx range. Such potential adaptability to diminished snow conditions, increasingly patchy and isolated boreal forests, and reduced hare abundance may be important to the taxon as a whole faced with a rapidly changing climate.

Given the high percentage of Federal land ownership in the West, regulatory commitments that these lands will continue to be managed in accordance with lynx conservation principles, and

the existence of potential high-elevation climate refugia to which lynx habitats and some lynx might move, the western geographic units (Units 3-6) may be more likely to support resident lynx longer under projected continued climate warming. Nonetheless, it is unlikely that any management actions can abate the long-term northward and upslope retreat of boreal forests and diminished snow conditions projected by climate models. Further, the size, frequency, and intensity of wildfires and forest insect outbreaks are expected to increase with continued climate warming, particularly in the western portion of the DPS, although we do not anticipate such events in-and-of-themselves are likely to cause the permanent loss of breeding lynx populations in any geographic unit.

Projections of climate-mediated losses of boreal forests and favorable snow conditions suggest impacts to lynx and hare populations throughout the DPS. However, persistence of resident lynx in Maine and Minnesota may be relatively lower than the western geographic units given the smaller percent of Federal lands and the absence of associated regulatory commitments to lynx conservation, and the lack of potential elevational refugia. Additionally, as noted above, changes to regulations governing timber harvest on private forest lands in Maine are unlikely to maintain the current historically-high amount and distribution of good lynx habitat or the current large population of resident lynx. These changes, which may affect over 90 percent of lynx habitats in northern Maine, are projected to result in substantial declines in habitat quality and distribution, and lynx numbers, over the next 10-30 years, primarily through restrictions on clearcutting and the proliferation of partial harvesting. On private forest lands, energy development (wind energy, mining), rapid turnover in ownership and parcelization of forest land, and uncertain forest markets may also reduce the future quality and quantity of lynx habitat.

DPS Viability

Resident lynx populations persisted historically and continue to persist in 4 geographic units (Units 1-4). It is uncertain whether Unit 5 (the GYA) historically supported a small persistent population or if lynx residency was ephemeral; currently, it appears not to support resident lynx. Available evidence suggests that Unit 6 (Colorado) did not historically support persistent lynx presence; however, a resident population has persisted there for more than a decade since the 1999-2006 releases described above. Considering the available information, we find no reliable evidence that the current distribution and relative abundance of resident lynx in the contiguous United States are substantially reduced from historical conditions. This suggests historical and current resiliency among lynx populations in the DPS.

The current broad distribution of resident lynx in large, geographically discrete areas (redundancy) makes the DPS invulnerable to extirpation caused by a single catastrophic event. Because we lack evidence that formerly persistent lynx populations have been lost from any large areas, it also seems that redundancy in the DPS has not been meaningfully diminished from historical levels. In fact, as a result of the current population in Colorado, redundancy in the DPS is likely greater, at least temporarily, now than it was historically.

Similarly, resident lynx remain broadly distributed across the range of habitats that has supported them historically, suggesting maintenance of the breadth and diversity of ecological settings occupied within the DPS range (representation). Additionally, observed high rates of dispersal and gene flow and, therefore, generally low levels of genetic differentiation across most of the lynx's range, including the DPS, suggest the past and recent genetic health of lynx populations in the DPS (representation; but see section 2.1). Because there are no indications of significant loss of or current stressors to the genetic health or adaptive capacity of lynx populations in the DPS, we find that the current level of representation within the DPS does not appear to indicate a decrease from historical conditions.

In the future, we expect lynx populations in each geographic unit to become smaller and more patchily-distributed due largely to projected climate-driven losses in habitat quality and quantity and related factors. However, the timing, rate, and extent of habitat decline due to projected climate warming and corresponding effects to lynx populations is highly uncertain. Despite some reduced resiliency, we conclude that resident lynx populations are very likely to persist in all 5 units that currently support them (Units 1-4 and 6) in the near-term (2025) and in all or most of those units at 2050, with corresponding maintenance of redundancy and representation in the DPS over that time span. We and the experts we consulted have low confidence in predicting the likely conditions of DPS populations beyond 2050. That said, smaller, more isolated populations would be less resilient and more vulnerable to demographic and environmental stochasticity and genetic drift and, therefore, at higher risk of extirpation. Although predictions out to 2100 are highly uncertain, it is possible that resident lynx populations could be functionally extirpated from some units by the end of the century. Should future extirpations occur, this would indicate a loss of resiliency, reduced redundancy and representation, and an increased risk of extirpation of the DPS.

Literature Cited

- 16 USC 1. National Park Service Organic Act Section 1, NPS Mission, as Amended. 5 pp.
- 16 USC 1131-1136. (1964). Wilderness Act. 6 pp.
- 16 USC 1600. National Forest Management Act of 1976. 13 pp.
- 36 CFR 219.22. The overall role of science in planning. <http://www.gpo.gov/fdsys/pkg/CFR-2011-title36-vol2/pdf/CFR-2011-title36-vol2-sec219-22.pdf>.
- 62 FR 28653. Endangered and Threatened Wildlife and Plants; 12-Month Finding for a Petition to List the Contiguous U.S. Distinct Population Segment of the Canada Lynx. May 27, 1997. https://ecos.fws.gov/docs/federal_register/fr3075.pdf.
- 65 FR 16052. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Contiguous U.S. Distinct Population Segment of the Canada Lynx and Related Rule. March 24, 2000. <http://www.gpo.gov/fdsys/pkg/FR-2000-03-24/pdf/00-7145.pdf>.
- 68 FR 40076. Endangered and Threatened Wildlife and Plants; Notice of Remanded Determination of Status for the Contiguous United States Distinct Population Segment of the Canada Lynx. July 3, 2003. <http://www.gpo.gov/fdsys/pkg/FR-2003-07-03/pdf/03-16664.pdf>.
- 71 FR 66008. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Contiguous United States Distinct Population Segment of the Canada Lynx. November 9, 2006. <https://www.gpo.gov/fdsys/pkg/FR-2006-02-16/pdf/06-1443.pdf#page=1>.
- 72 FR 1186. Endangered and Threatened Wildlife and Plants; Clarification of Significant Portion of the Range for the Contiguous United States Distinct Population Segment of the Canada Lynx. January 10, 2007. <https://www.gpo.gov/fdsys/pkg/FR-2007-01-10/pdf/E6-22633.pdf#page=1>.
- 72 FR 19549. Endangered and Threatened Wildlife and Plants; Initiation of 5-Year Reviews of Seven Wildlife Species and Two Plant Species in the Mountain-Prairie Region. Notice of review; request for comments. April 18, 2007. <https://www.gpo.gov/fdsys/pkg/FR-2009-02-25/pdf/E9-3512.pdf#page=2>.
- 74 FR 8616. Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for the Contiguous United States Distinct Population Segment of the Canada Lynx; Final Rule. February 25, 2009. <https://www.gpo.gov/fdsys/pkg/FR-2009-02-25/pdf/E9-3512.pdf#page=2>.
- 74 FR 66937. Endangered and Threatened Wildlife and Plants; 12-month Finding on a Petition To Change the Final Listing of the Distinct Population Segment of the Canada Lynx To

- Include New Mexico. December 17, 2009. <https://www.gpo.gov/fdsys/pkg/FR-2009-12-17/pdf/E9-29960.pdf#page=1>.
- 75 FR 6539. Healthy Forest Reserve Program. February 10, 2010. <http://www.gpo.gov/fdsys/pkg/FR-2010-02-10/pdf/2010-2812.pdf>
<http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/forests/>.
- 78 FR 59430. Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for the Contiguous U.S. Distinct Population Segment of the Canada Lynx and Revised Distinct Population Segment Boundary; Proposed Rule. September 26, 2013. <https://www.gpo.gov/fdsys/pkg/FR-2013-09-26/pdf/2013-23189.pdf>.
- 79 FR 54782. Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for the Contiguous United States Distinct Population Segment of the Canada Lynx and Revised Distinct Population Segment Boundary; Final Rule. September 12, 2104. <https://www.gpo.gov/fdsys/pkg/FR-2014-09-12/pdf/2014-21013.pdf>.
- 78 Stat. 890. (1964). Wilderness Act. 7 pp.
- Abatzoglou, J. T. 2011. Influence of the PNA on declining mountain snowpack in the Western United States. *International Journal of Climatology* 31:1135-1142.
- Abatzoglou, J. T. and C. A. Kolden. 2013. Relationships between climate and macroscale area burned in the western United States. *International Journal of Wildland Fire* 22:1003–1020.
- Abele, S. L., A. J. Wirsing, and D. L. Murray. 2013. Precommercial forest thinning alters abundance but not survival of snowshoe hares. *The Journal of Wildlife Management* 77:84-92.
- Agee, J. K. 2000. Disturbance ecology of North American boreal forests and associated northern mixed/subalpine forests. Pages 39-82 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). *Ecology and conservation of lynx in the contiguous United States*. University Press of Colorado, Boulder, Colorado.
- Ahn, S., W. B. Krohn, A. J. Platinga, and T. J. Dalton. 2002 Agricultural land changes in Maine: A compilation and brief analysis of Census of Agriculture data, 1850-1997. Maine Agricultural and Forest Experiment Station Technical Bulletin 182. http://digitalcommons.library.umaine.edu/aes_techbulletin/26/.
- Alaska Natural Heritage Program. 2008. Conservation status report. *Lynx canadensis*. 7 pp.
- Albrecht, N. M., and C. L. Heusser. 2009. Detecting the presence of fishers and lynx on the ceded territory of the Coeur d'Alene Tribe. Coeur d'Alene Tribe, Plummer, Idaho, USA.
- Alexander, S. M., N. M. Waters, and P. C. Paquet. 2005. Traffic volume and highway permeability for a mammalian community in the Canadian Rocky Mountains. *Canadian Geographer* 49:321–331.

- Allen, C. D., A. K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D. D. Breshears, E. H. Hogg. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* 259:660-684.
- Amiro, B. D., A. L. Orchansky, A. G. Barr, T. A. Black, S. D. Chambers, F. S. Chapin III, M. L. Goulden, M. Litvak, H. P. Liu, J. H. McCaughley, A. McMillan, and J. T. Randerson. 2006. The effect of post-fire stand age on the boreal forest energy balance. *Agricultural and Forest Meteorology* 140:41-50.
- Anderson, E.M. and M.J. Lovallo. 2003. Bobcat and Lynx. Pages 758-786 in G.A. Feldhamer, B.C. Thompson, and J.A. Chapman, eds. *Wild Mammals of North America: Biology, Management, and Conservation*. Johns Hopkins University Press.
- Andrews, C. 2016. Modeling and forecasting the influence of current and future climate on eastern North American spruce-fir (*Picea abies*) forests. M.S. Thesis, University of Maine, Orono, Maine. <http://digitalcommons.library.umaine.edu/etd/2562>.
- Apps, C. D. 2000. Space-use, diet, demographics, and topographic associations of lynx in the southern Canadian Rocky Mountains: a study. Pages 351-371 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). *Ecology and conservation of lynx in the contiguous United States*. University Press of Colorado, Boulder, Colorado.
- Apps, C. D. 2007. Ecology and conservation of Canada lynx in the Southern Canadian Rocky Mountains. Ph.D. Dissertation, University of Calgary, Calgary, Alberta, Canada. xvi + 242 pp.
- Apps, C. D., J. L. Weaver, P. C. Paquet, B. Bateman, and B. N. McLellan. 2007. Carnivores in the southern Canadian Rockies: core areas and connectivity across the Crowsnest Highway. Wildlife Conservation Society Canada Conservation Report No 3. Toronto, Ontario, Canada. <http://www.wcscanada.org/LinkClick.aspx?fileticket=bLGCcLWSCY%3d&tabid=2561>.
- Ashfaq, M., S. Ghosh, S.-C. Kao, L. C. Bowling, P. Mote, D. Touma, S. A. Rauscher, and N. S. Diffenbaugh. 2013. Near-term acceleration of hydroclimatic change in the western U.S. *J. Geophys. Res. Atmos.* 118:10,676–10,693, doi:10.1002/jgrd.50816.
- Assells, A., H. Boulanger, B. Martin and M. C. Pelletier-Leclerc. 2007. Suivi de l'abondance du lièvre d'Amérique (*Lepus americanus*), de 2000 à 2006 dans sept régions du Québec. Page 38 Ministère des Ressources naturelles et de la Faune. Direction de l'aménagement de la faune, Gaspésie-îles-de-la-Madeleine.
- Aubry, K.B. 2006. Peer review of USFWS 2006 proposed rule to designate critical habitat for the contiguous U.S. distinct population segment of Canada lynx. May 2, 2006, letter to USFWS. 3 pp.
- Aubry, K. B., G. M. Koehler, and J. R. Squires. 2000. Ecology of Canada lynx in southern boreal forests. Pages 373-396 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). *Ecology and conservation of lynx in the contiguous United States*. University Press of Colorado, Boulder, Colorado.

- Auclair, A., W. Heilman, and B. Brinkman. 2010. Predicting forest dieback in Maine, USA: a simple model based on soil frost and drought. *Can. J. For. Res.* 40: 687–702.
- Ausband, D. E. and G. R. Baty. 2005. Effects of precommercial thinning on snowshoe hare habitat use during winter in low-elevation montane forests. *Canadian Journal of Forest Research* 35:206-210.
- Baigas, P. E., J. R. Squires, L. E. Olson, J. S. Ivan, and E. K Roberts. 2017. Using environmental features to model highway crossing behavior of Canada lynx in the Southern Rocky Mountains. *Landscape and Urban Planning* 157:200–213.
- Bailey, T. N., E. E. Bangs, M. F. Portner, J. C. Malloy, and R. J. McAvinchey. 1986. An apparent overexploited lynx population on the Kenai Peninsula, Alaska. *Journal of Wildlife Management* 50:279–290.
- Baldwin, E. D., L. S. Kenefic, and W. F. LaPage. 2007. Alternative large-scale conservation visions for Northern Maine: Interviews with decision leaders in Maine.” *Maine Policy Review* 16(2): 78–91.
- Barbero, R., J. T. Abatzoglou, E. A. Steel, and N. K. Larkin. 2014. Modeling very large-fire occurrences over the continental United States from weather and climate forcing. *Environmental Research Letters* 9:124009.
- Barbero, R., J. T. Abatzoglou, N. K. Larkin, C. A. Kolden, and B. Stocks. 2015. Climate change presents increased potential for very large fires in the contiguous United States. *International Journal of Wildland Fire*. <http://dx.doi.org/10.1071/WF15083>.
- Barbour and Litvaitis 1993 Niche dimensions of New England cottontails in relation to habitat patch size. *Oecologia* 93:321-327.
- Basille, M., I. Herfindal, H. Santin-Janin, J. D. C. Linnell, J. Odden, R. Andersen, K. A. Hogda, and J. M. Gaillard. 2009. What shapes Eurasian lynx distribution in human dominated landscapes: selecting prey or avoiding people? *Ecography* 32:683-691.
- Baumgartner, D. M., R. G. Krebill, J. T. Arnott, and G. F. Weetman, editors. 1984. Lodgepole pine: the species and its management. Symposium proceedings; May 8–10, 1984; Spokane, WA; May 14–16, 1984; Vancouver, British Columbia.
- Bayne, E. M., S. Boutin, and R. A. Moses. 2008. Ecological factors influencing the spatial pattern of Canada lynx relative to its southern range edge in Alberta, Canada. *The Canadian Journal of Zoology* 86:1189-1197.
- Beck, G, G. Keesler, and L. Maxwell. 2012. State of large landscape conservation in Maine 2012. Colby College, Waterville, Maine <http://web.colby.edu/stateofmaine2012/state-of-large-landscape-conservation-in-maine/>.
- Beckage, B., B. Osborne, D. G. Gavin, C. Pucko, T. Siccama, and T. Perkins. 2008. A rapid upward shift of a forest ecotone during 40 years of warming in the Green Mountains of Vermont. *Proceedings of the National Academy of Sciences* 105:4197-4202.

- Bellefeuille, S., L. Belanger, J. Huot, and A. Cimon. 2001. Clear-cutting and regeneration practices in Quebec boreal balsam fir forest: effects on snowshoe hare. *Canadian Journal of Forest Research* 31:41-51.
- Beniston, M. 2016. Environmental changes in mountains and uplands. Routledge, Taylor and Francis Group. London and New York.
- Benjamin, J., R. J. Lilleholm, and D. Damery. 2009. Challenges and opportunities for the Northeastern forest bioindustry. *Journal of Forestry* 107:125-131.
- Bentz, B. J., editor. 2009. Bark beetle outbreaks in western North America: causes and consequences. Bark Beetle Symposium, Snowbird, Utah, November 2005. 42pp. http://www.fs.fed.us/rm/pubs_other/rmrs_2009_bentz_b001.pdf.
- Bentz, B. J., J. Regniere, C. J. Fettig, E. M. Hansen, J. L. Hayes, J. A. Hicke, R. G. Kelsey, J. F. Negrón, and S. J. Seybold. 2010. Climate change and bark beetles of the western United States and Canada: direct and indirect effects. *BioScience* 60:602-613.
- Berg, N. D. 2009. Beaverhead-Deerlodge National Forest Canada lynx and snowshoe hare habitat and track surveys. Unpubl. report, USDA Forest Service, Beaverhead-Deerlodge National Forest, Dillon, Montana. 22 pp.
- Berg, N. D. 2010. Snowshoe hare and forest structure relationships in western Wyoming. M. S. Thesis, Utah State University, Logan, Utah. 86 pp.
- Berg, N. D. 2016. Personal communication re: Lynx Expert Elicitation Workshop Report; electronic mail to J. Zelenak, USFWS, Helena, MT, May 31, 2016.
- Berg, N. D. and E. M. Gese. 2010. Relationship between fecal pellet counts and snowshoe hare density in western Wyoming. *The Journal of Wildlife Management* 74:1745-1751.
- Berg, N. D. and R. M. Inman. 2010. Uinta Mountain lynx and wolverine survey report. Unpubl. report, USDA Forest Service, Uinta-Wasatch-Cache and Ashley National Forests, Utah. 44 pp.
- Berg, N. D., E. M. Gese, J. R. Squires, and L. M. Aubry. 2012. Influence of forest structure on the abundance of snowshoe hares in western Wyoming. *Journal of Wildlife Management* 76:1480-1488.
- Bergeron, Y. and M. D. Flannigan. 1995. Predicting the effects of climate change on fire frequency in the southeastern Canadian boreal forest. *Water Air Soil Pollution* 82:437-444.
- Bergeron, Y., S. Gauthier, V. Kafta, P. Lefort, and D. Lesieur. 2001. Natural fire frequency for the eastern Canadian boreal forest: consequences for sustainable forestry. *Canadian Journal of Forestry Research* 31:384-391.
- Bergeron, Y., D. Cyr, M. P. Girardin, and C. Carcaillet. 2010. Will climate change drive 21st century burn rates in Canadian boreal forest outside of its natural variability: collating global climate model experiments with sedimentary charcoal data. *International Journal of Wildland Fire* 19:1127-1139.

- Bernier, C. 2015. Untitled. Response to U.S. Fish and Wildlife Service request for information on Canada lynx. Vermont Fish & Wildlife Department, Montpelier, VT. 7 pp.
- Bernier, C. 2016. Personal communication re: Request for update about lynx in VT from USFWS; electronic mail reply to J. Zelenak, USFWS, Helena, MT, June 6, 2016.
- Biek, R., R. L. Zarnke, C. Gillin, M. Wild, J. R. Squires, and M. Poss. 2002. Serologic survey for viral and bacterial infections in western populations of Canada lynx (*Lynx canadensis*). *Journal of Wildlife Diseases* 38:840-845.
- Bittner, S. L. and O. J. Rongstad. 1982. Snowshoe hare and allies. Pages 146-163 in J. A. Chapman and G. A. Feldhamer (eds.). *Wild mammals of North America biology, management and economics*. Johns Hopkins University Press, Baltimore, MD.
- Bjornlie, N. 2016. Personal communication re: WY/GYA lynx questions; electronic mail reply to J. Zelenak, USFWS, Helena, MT, Feb. 10, 2016.
- Blais, J. R. 1983. Trends in the frequency, extent, and severity of spruce budworm outbreaks in eastern Canada. *Canadian Journal of Forest Research* 13:539-547.
- BLM. 2004a. Environmental Assessment: Canada Lynx Amendment to the Garnet Resource Management Plan (RMP). Missoula Field Office. 11 pp.
- BLM. 2004b. Biological Assessment: Canada Lynx Amendment, Garnet Resource Management Plan (RMP). Missoula Field Office. 12 pp.
- BLM. 2008. Record of Decision and Approved Pinedale Resource Management Plan, Appendix 18 - Threatened, Endangered and BLM Sensitive Species with the Potential to Occur in the Pinedale Planning Area. 42 pp.
- BLM. 2010. Record of Decision and Approved Kemmerer Resource Management Plan, Appendix A - Conservation Measures for Threatened or Endangered Species; Conservation Agreements, and BLM-Endorsed Management Strategies for Special Status Species. 17 pp.
- BLM and USFWS. 2000. Canada Lynx Conservation Agreement. 12 pp.
- Borrecco, J. E. 1976. Controlling damage by forest rodents and lagomorphs through habitat manipulation. In *Proceedings: Seventh Vertebrate Pest Conference*, C. S. Siebe, editor. March 9–11, 1976, Monterey, California, USA.
- Brainerd, S. M. 1985. Reproductive ecology of bobcats and lynx in western Montana. M. S. Thesis, Univ. of Montana, Missoula. 85 pp.
- Brand, C. J. and L. B. Keith. 1979. Lynx demography during a snowshoe hare decline in Alberta. *Journal of Wildlife Management* 43:827-849.
- Brand, C. J., L. B. Keith, and C. A. Fischer. 1976. Lynx responses to changing snowshoe hare densities in central Alberta. *Journal of Wildlife Management* 40:416-428.

- Breitenmoser, U., B. G. Slough, and C. Breitenmoser-Würsten. 1993. Predators of cyclic prey: Is the Canada lynx victim or profiteer of the snowshoe hare cycle? *Oikos* 66:551-554.
- British Columbia Wildlife Accident Reporting System. 2012. B.C. Ministry of Transportation and Infrastructure, Victoria, B.C. *as cited on p. 78 in*: Interagency Lynx Biology Team (ILBT). 2013. Canada lynx conservation assessment and strategy. 3rd edition. USDA Forest Service, USDI Fish and Wildlife Service, USDI Bureau of Land Management, and USDI National Park Service. Forest Service Publication #R1-13-19, Missoula, MT. 128 pp.
- Brocke, R. H., K. A. Gustafson, and L. B. Fox. 1991. Restoration of large predators: potentials and problems. Pages 303-315 in *Challenges in the conservation of biological resources. A practitioner's guide*. D. J. Decker, M. E. Krasny, G. R. Goff, C. R. Smith, and D. W. Gross, eds. Westview Press, Boulder, CO. Brocke, R. H., K. A. Gustafson, and L. B. Fox. 1992. Restoration of large predators: Potentials and problems.
- Brocke, R. H., J. L. Belant, and K. A. Gustafson. 1993. Lynx population and habitat survey in the White Mountain National Forest, New Hampshire. State University of New York, Syracuse. 96 pp. + App.
- Brooks, D. R. and E. P. Hoberg. 2007. How will global climate change affect parasite-host assemblages? *Trends in Parasitology* 23: 571-574.
- Brown, R. D. 2000. Northern hemisphere snow cover variability and change, 1915-97. *Journal of Climate* 13:2339-2355.
- Brown, R. D. and R. O. Braaten. 1998. Spatial and temporal variability of Canadian monthly snow depths, 1946–1995. *Atmosphere-Ocean* 36:37-54.
- Buehler, D. A. and L. B. Keith. 1982. Snowshoe hare distribution and habitat use in Wisconsin. *Canadian Field-Naturalist* 96:19-29.
- Bull, E. L., T. W. Heater, A. A. Clark, J. F. Shepherd, and A. K. Blumton. 2005. Influence of precommercial thinning on snowshoe hares. USDA Forest Service, Pacific Northwest Research Station, Research Paper PNW-RP-562.
- Burakowski, E. A., C. P. Wake, B. Braswell, and D. P. Brown. 2008. Trends in wintertime climate in the northeastern United States: 1965–2005. *Journal of Geophysical Research: Atmospheres*, 113(D20).
- Burdett, C. L. 2008. Hierarchical structure of Canada lynx space use and habitat selection in Northeastern Minnesota. PhD Dissertation. University of Minnesota.
- Burdett, C. L., R. A. Moen, G. J. Niemi, and L. D. Mech. 2007. Defining space use and movements of Canada lynx with global positioning system telemetry. *Journal of Mammalogy* 88:457-467.
- Burns, C., M. Hunter, P. deMaynadier, L. Incze, W. Krohn, P. Vaux, and B. Vickery. 2009. Biodiversity. Pages 30-36 in Jacobson, G. L., I. J. Fernandez, P. A. Mayewski, and C. V. Schmitt (editors). 2009. *Maine's Climate Future: An Initial Assessment*. Orono, ME: University of Maine. http://climatechange.umaine.edu/files/Maines_Climate_Future.pdf.

- Burton, D. M., B. A. McCarl, C. N. M. deSousa, D. M. Adams, R. J. Alig, and S. M. Winnett. 1998. Economic dimensions of climate change on southern forests. Chapter 42 in R. A. Mickler et al. 1998. The productivity and sustainability of southern forest ecosystems in a changing environment. Springer-Verlag, New York, New York, USA.
- Buskirk, S. W., L. F. Ruggiero, and C. J. Krebs. 2000a. Habitat fragmentation and interspecific competition: implications for lynx conservation. Pages 83-100 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). Ecology and conservation of lynx in the contiguous United States. University Press of Colorado, Boulder, Colorado.
- Buskirk, S. W., L. F. Ruggiero, K. B. Aubry, D. E. Pearson, J. R. Squires, and K. S. McKelvey. 2000b. Comparative ecology of lynx in North America. Pages 397-417 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). Ecology and conservation of lynx in the contiguous United States. University Press of Colorado, Boulder, Colorado.
- Calkin, D. E., M. P. Thompson, and M. A. Finney. 2015. Negative consequences of positive feedbacks in U. S. wildfire management. *Forest Ecosystems* 2:1-10.
- Callaghan, M., M. Johansson, R. D. Brown, P. Y. Groisman, N. Labba, V. Radionov, R. G. Barry, O. N. Bulygina, R. L. H. Essery, D. M. Frolov, V. N. Golubev, T. C. Greenfell, M. N. Petrushina, V. N. Razuvaev, D. A. Robinson, P. Romanov, D. Shindell, A. B. Shmakin, S. A. Sokratov, S. Warren, and D. Yang. 2011. The changing face of arctic snow cover: a synthesis of observed and projected changes. *AMBIO* 40:17-31.
- Carroll, C. 2007. Interacting effects of climate change, landscape conversion, and harvest on carnivore populations at the range margin: marten and lynx in the Northern Appalachians. *Conservation Biology* 21:1092-1104.
- Carroll, C., R. F. Noss, and P. C. Paquet. 2001. Carnivores as focal species for conservation planning in the Rocky Mountain region. *Ecological Applications* 11:961-980.
- Carter, T. R. 1996. Assessing climate change adaptations: The IPCC guidelines. In *Adapting to Climate Change: An International Perspective*, ed. J.B. Smith, N. Bhatti, G.V. Menshulin, R. Benioff, M. Campos, B. Jallow, F. Rijsberman, M.I. Budyko and R.K. Dixon, Springer, Berlin.
- Catton, T. J., D. Ryan, and D. Grosshuesch. 2015. Summary of the Superior National Forest's 2015 Canada lynx (*Lynx Canadensis*) DNA database. October 28. 6pp.
- Cayan, D. R., S. A. Kammerdiener, M. D. Dettinger, J. M. Caprio, and D. H. Peterson. 2001. Changes in the onset of spring in the western United States. *Bulletin of the American Meteorological Society* 82:399-415.
- Christensen, N. S., A. W. Wood, N. Voisin, D. P. Lettenmaier, and R. N. Palmer. 2004: Effects of climate change on the hydrology and water resources of the Colorado River Basin. *Climatic Change* 62:337-363.
- Christensen, J. H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R. K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C. G. Menéndez, J. Räisänen, A.

- Rinke, A. Sarr and P. Whetton, 2007: Regional Climate Projections. Pages 847-940 in: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html.
- Clevenger, A. P. and N. Waltho. 2005. Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. *Biological Conservation* 121:453-464.
- Clevenger, A. P., B. Chruszcz, and K. E. Gunson. 2001. Highway mitigation fencing reduces wildlife-vehicle collisions. *Wildlife Society Bulletin* 29:646-653.
- Cogbill, C. V. 1985. Dynamics of the boreal forests of the Laurentian Highlands, Canada. *Canadian Journal of Forest Research* 15:252-261.
- Colorado Division of Wildlife. 2000. Colorado lynx recovery project: 2000 progress report to the U.S. Fish and Wildlife Service. Glenwood Springs, CO. 16 pp.
- C. R. S. 33-2-105. Colorado Revised Statutes Title 33-2-105.
- C. R. S. 33-6-205. Colorado Revised Statutes Title 33-6-205.
- C. R. S. 33-6-207. Colorado Revised Statutes Title 33-6-207.
- Confederated Salish and Kootenai Tribes. 2000. Flathead Indian Reservation Forest Management Plan. 308 pp.
- Confederated Salish and Kootenai Tribes. 2014a. Tribal Natural Resources Department, Division of Fish, Wildlife, Recreation, Conservation.
- Confederated Salish and Kootenai Tribes. 2014b. Tribal Wildlife Management Program Plan Fiscal Year 2014. 10 pp.
- Conroy, M. J., L. W. Gysel, and G. R. Dudderar. 1979. Habitat components of clear-cut areas for snowshoe hares in Michigan. *Journal of Wildlife Management* 43:680-690.
- Cornulier, T., N. G. Yoccoz, V. Bretagnolle, J. E. Brommer, A. Butet, F. ecke, D. A. Elston, E. Framstad, H. Hentonen, B. Hornfeldt, O. Huitu, C. Imholt, R. A. Ims, J Jacob, B. Jedrzejewska, A. Million, S. J. Petty, H. Pietiainen, E. Tkadlec, K. Zub, and X. Lambin. 2013. Europe-wide dampening of population cycles in keystone herbivores. *Science* 340:63-66.
- Courville, S. 2014. Personal communication: telephone call between S. Courville, Wildlife Biologist, Confederated Salish and Kootenai Tribes (CSKT) of the Flathead Nation - Flathead Reservation, and J. Zelenak, USFWS, Helena, MT, April 30, 2014.
- Cox, E. W., R. A. Garrott, and J. R. Cary. 1997. Effect of supplemental cover on survival of snowshoe hares and cottontail rabbits in patchy habitat. *Canadian Journal of Zoology* 75:1357-1363.

- CPW. 2015. 2015 Colorado Small Game. Colorado Parks and Wildlife, Denver, CO. 16 pp.
- Crooks, K. R. 2002. Relative sensitivities of mammalian carnivores to habitat fragmentation. *Conservation Biology* 16:488-502.
- Cummings, J. 2016. Lynx EE (Expert Elicitation) figures. U.S. Geological Survey, Patuxent Wildlife Research Center. 20 pp.
- Daggett, R. H. 2003. Long-term effects of herbicide and precommercial thinning treatments on species composition, stand structure, and net present value in spruce–fir stands in Maine: The Austin Pond Study. M. S. Thesis, University of Maine, Orono. 136 pp.
- Dale, V. H., L. A. Joyce, S. McNulty, R. P. Neilson, M. P. Ayres, M. D. Flannigan, P. J. Hanson, L. C. Irland, A. E. Lugo, C. J. Peterson, D. Simberloff, F. J. Swanson, B. J. Stocks, and B. M. Wotton. 2001. Climate change and forest disturbances. *BioScience* 51:723-734.
- Dalquest, W. W. 1942. Geographic variation in northwestern snowshoe hares. *Journal of Mammalogy* 23:166-183.
- Danby, R. K. and D. S. Hik. 2007. Variability, contingency, and rapid change in recent subarctic alpine tree line dynamics. *Journal of Ecology* 95:352-363.
- Daniel, T. W., Helms, J. A. and Baker, F. S. 1979. *Principles of Silviculture*. McGraw-Hill, New York, New York, USA. 500 pp.
- Daszak, P., A. A. Cunningham, A. D. Hyatt. 2000. Emerging infectious diseases of wildlife - threats to biodiversity and human health. *Science* 287:443-449.
- Davidson, R., M. Simard, S. J. Kutz, C. M. O. Kapel, I. S. Hamnes, and L. J. Robertson. 2011. Arctic parasitology: why should we care? *Trends in Parasitology* 27:239-245.
- Decker, K and M. Fink. 2014. Colorado Wildlife Action Plan Enhancement: Climate Change Vulnerability Assessment. Colorado Natural Heritage Program, Colorado State University, Fort Collins. 129 pp.
- deGooyer, K. and D. E. Capen. 2004. An analysis of conservation easements and forest management in New York, Vermont, New Hampshire, and Maine. Prepared for the Northeast States Foresters Association.
http://www.nefainfo.org/uploads/2/7/4/5/27453461/nefa_final_report_7.2004.pdf.
- DeHayes, D. H., G. L. Jacobson, P. G. Schaber, B. bongarten, L. R. Iverson, and A. Dieffenbacker-Krall. 2000. Forest responses to changing climates: lessons from the past and uncertainty for the future. *In* Responses of northern forests to environmental change. *Ecological Studies* 139. Edited by R. A. Mickler, R. A. Birdsey, and J. L. Horn. Springer-Verlag, New York, Perline, Heidelberg. pp. 495-540.
- Dennison, P. E., S. C. Brewer, J. D. Arnold, and M. A. Moritz. 2014. Large wildfire trends in the western United States, 1984–2011. *Geophysical Research Letters* 41:928–2933. doi:10.1002/2014GL059576.

- Deschampe, N. W. 2008. Letter Re: Critical habitat designation for lynx. Grand Portage Reservation Tribal Council. 3 pp.
- Deser, C., A. S. Phillips, M. A. Alexander, and B. V. Smoliak. 2014. Projecting North American climate over the next 50 years: Uncertainty due to internal variability. *Journal of Climate* 27:2271–2296.
- Devineau, O., T. M. Shenk, G. C. White, P. F. Doherty, Jr., P. M. Lukacs, and R. H. Kahn. 2010. Evaluating the Canada lynx reintroduction programme in Colorado: patterns in mortality. *Journal of Applied Ecology* 47:524-531.
- Diaz, H. F. and J. K. Eischeid. 2007. Disappearing “alpine tundra” Koppen climatic type in the western United States. *Geophysical Research Letters* 34:L18707.
- Diefenbach, D. R., S. L. Rathbun, J. K. Vreeland, D. Grove, and W. J. Kanapaux. 2016. Evidence for range contraction of snowshoe hare in Pennsylvania. *Northeastern Naturalist* 23:229-248.
- Dolbeer, R. A. and W. R. Clark. 1975. Population ecology of snowshoe hares in the central Rocky Mountains. *Journal of Wildlife Management* 39:535-549.
- Dobrowski, S. Z. 2011. A review basis for microrefugia: the influence of terrain on climate. *Global Change Biology* 17:1022-1035.
- Dudley, R. W. and G. A. Hodgkins. 2002. Trends in streamflow, river ice, and snowpack for coastal river basins in Maine during the 20th century (No. 2002-4245). Geological Survey (US).
- Dunning, J. B., B. J. Danielson, and H. R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. *Oikos* 65:169-175.
- Dyer, J. L. and T. L. Mote. 2006. Spatial variability and trends in observed snow depth over North America. *Geophysical Research Letters* 33:L16503.
- Eagar, C. and M. B. Adams. 2012. Ecology and decline of red spruce in the eastern United States. Springer-Verlag, New York, New York, U. S. A.
- Elliot-Fisk, D. L. 1988. The boreal forest. Pages 33-62 *in* Barbour, M.G. and W.D. Billings (eds.). North American terrestrial vegetation. Cambridge Univ. Press, Cambridge.
- Ellsworth, E. 2009. Snowshoe hare nutrition in a conifer forest: effects of winter food on energy use, activity, and demography in a low-density population. Ph.D. Dissertation, University of Idaho, Moscow. xv + 107 pp.
- Elton, C. and M. Nicholson. 1942. The ten-year cycle in numbers of the lynx in Canada. *Journal of Animal Ecology* 11:215-244.
- Endeavor Wildlife Research. 2008. Endeavor Wildlife Research Foundation Greater Yellowstone lynx study Canada lynx track locations. Unpublished data. 2pp.

- Endeavor Wildlife Research. 2009. Greater Yellowstone Ecosystem Lynx Study. Unpublished Report. 30 pp.
- Environment Canada 2014. Non-detriment finding for Canada lynx. Publ. 2007-10-25; revised 2014-02-17. 4 pp.
- Erb, J. 2012. Registered furbearer harvest statistics. 2011-2012 Report. Grand Rapids, MN. 30 pp.
- Erb, J. 2014. Furbearer winter track survey summary, 2014. Pp. 39-46 *in* Carnivore scent station survey and winter track indices. Forest Wildlife Populations and Research Group, Grand Rapids, MN. 18 pp. (pp. 29-46).
- Etheridge, D. A., D. A. MacLean, R. G. Wagner, and J. S. Wilson. 2005. Changes in landscape composition and stand structure from 1945 2002 on an industrial forest in New Brunswick, Canada. *Canadian Journal of Forest Research* 35:1965-1977.
- Fagre, D. B. 2005. Adapting to the reality of climate change at Glacier national Park, Montana, USA. *Proceedings I Conferencia Cambio Climático, Bogotá 2005*. 14 pp.
- Farrell, L. E. 2012. Northeastern meso-mammals: landscape use and detection. Doctoral dissertation, University of Vermont.
- Farrell, L. E. 2013. Personal communication; telephone call between Farrell, primary author and former University of Vermont PhD student, and A. Tur, Endangered Species Biologist, USFWS, New England Field Office, April 30, 2013.
- Feierabend, D. and K. Kielland. 2014. Multiple crossings of a large glacial river by Canada lynx (*Lynx canadensis*). *The Canadian Field Naturalist* 128:80-83.
- Feng, S. and Q. Hu. 2007. Changes in winter snowfall/precipitation ratio in the contiguous United States. *Journal of Geophysical Research* 112:D15109, doi:10.1029/2007JD008397.
- Ferreras, P. 2001. Landscape structure and asymmetrical inter-patch connectivity in a metapopulation of the endangered Iberian lynx. *Biological Conservation* 100: 125-136.
- Ferron, J. and J. P. Ouellet. 1992. Daily partitioning of summer habitat and use of space by the snowshoe hare in southern boreal forest. *Canadian Journal of Zoology* 70:2178-2183.
- Fernandez, I.J., C. Schmitt, E. Stancioff, S.D. Birkel, and A. Pershing. 2015. Maine's Climate Future: 2015 Update. Climate Change Institute Faculty Scholarship. Paper 5. http://digitalcommons.library.umaine.edu/climate_facpub/5.
- Flannigan, M. D., Y. Bergeron, O. Engelmark, and B. M. Wotton. 1998. Future wildfire in circumboreal forests in relation to global warming. *Journal of Vegetation Science* 9:469-476.
- Flannigan, M., I. Campbell, M. Wotton, C. Carcaillet, P. Richard, and Y. Bergeron. 2001. Future fire in Canada's boreal forest: paleoecology results and general circulation model – regional climate model simulations. *Canadian Journal of Forest Resources* 31:854-864.

- Flannigan, M., B. Stocks, M. Turetsky, and M. Wotton. 2009. Impacts of climate change on fire activity and fire management in the circumboreal forest. *Global Change Biology* 15:549-560.
- Folland, C.K., T.R. Karl, J.R. Christy, R.A. Clarke, G.V. Grunz, J. Jouzel, ... P. Zhai et al. 2001. Observed climate variability and change, in *Climate Change. The Scientific Basis* edited by J.T. Houghton, et al., pp. 99-181, Cambridge Univ. Press, New York, 2001.
- Forest Stewardship Council. FSC-US Forest Management Standard (v1.0). <https://us.fsc.org/en-us/certification/forest-management-certification>.
- Forman, R. T. and L. E. Alexander. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics* 29:207-231.
- Fox, J. F. 1978. Forest fires and the snowshoe hare-Canada lynx cycle. *Oecologia* 31:349-374.
- Frelich, L. E. and P. B. Reich. 1995. Spatial patterns and succession in a Minnesota southern-boreal forest. *Ecological Monographs* 65:325-346.
- Friedlingstein, R., R. M. Andrew, J. Rogelj, G. P. Peters, J. G. Canadell, R. Knutti, G. Luderer, M. R. Raupach, M. Schaeffer, D. P. van Vuuren, and C. LeQuere. 2014. Persistent growth of Co2 emissions and implications for reaching climate targets. *Nature Geoscience* 7:709-715.
- Friedman, S. K. and P. B. Reich. 2005. Regional legacies of logging: Departure from presettlement forest conditions in northern Minnesota. *Ecological Applications*. 15:726-744.
- Fuller, A. K. 1999. Influence of partial harvesting on American marten and their primary prey in northcentral Maine. M.Sc. thesis, University of Maine, Orono, Maine. 141pp.
- Fuller, T. K., and D. M. Heisey. 1986. Density-related changes in winter distribution of snowshoe hares in northcentral Minnesota. *Journal of Wildlife Management* 50:261-264.
- Fuller, A. K. and D. J. Harrison. 2005. Influence of partial timber harvesting on American martens in north-central Maine. *Journal of Wildlife Management* 69:710-722.
- Fuller, A. K. and D. J. Harrison. 2010. Movement paths reveal scale-dependent habitat decisions by Canada lynx. *Journal of Mammalogy* 91:1269-1279.
- Fuller, A. K. and D. J. Harrison. 2013. Modeling the influence of forest structure on microsite habitat use by snowshoe hares. *Journal of Forestry Research* 2013:1-7.
- Fuller, A. K., D. J. Harrison, and H. J. Lachowski. 2004. Stand scale effects of partial harvesting and clearcutting on small mammals and forest structure. *Forest Ecology and Management* 191:373-386.
- Fuller, A. K., D. J. Harrison, and J. H. Vashon. 2007. Winter habitat selection by Canada lynx in Maine: prey abundance or accessibility? *Journal of Wildlife Management* 71:1980-1986.

- Fuss, S., J. G. Canadell, G. P. Peters, M. Tavonni, R. M. Andrew, P. Ciais, R. B. Jackson, C. D. Jones, F. Kraxner, N. Nakicenovic, C. LeQuere, M. R. Raupach, A. Sharifi, P. Smith, and Y. Yamagata. 2014. Betting on negative emissions. *Nature Climate Science* 4:850-853.
- Galatowitsch, S., L. Frelich, and L. Phillips-Mao. 2009. Regional climate change adaptation strategies for biodiversity conservation in a midcontinental region of North America. *Biological Conservation* 142:2012-2022.
- Garfin, G., G. Franco, H. Blanco, A. Comrie, P. Gonzalez, T. Piechota, R. Smyth, and R. Waskom. 2014. Ch. 20: Southwest. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 462-486. doi:10.7930/J08G8HMN. <http://nca2014.globalchange.gov/report/regions/southwest>.
- Gehman, S., A. Edmonds, and B. Robinson. 2004. Snowtracking surveys for lynx and other carnivores in the North and Middle Forks Flathead River System – Glacier National Park and Flathead National Forest winter 2003-2004. Unpubl. Report, Wild Things Unlimited, Bozeman, Montana. 56 pp.
- Gehman, S., M. Porco, and B. Robinson. 2010. Rare carnivore surveys on the Gallatin National Forest: Year thirteen annual project report, June 2010. Unpubl. Report, Wild Things Unlimited, Bozeman, Montana, 12 pp.
- Gehman, S., B. Robinson, G. Treinish, and K. Baughan. 2011. Snow-tracking surveys on the Helena National Forest, December 2010-April 2011. Unpubl. Report, Wild Things Unlimited, Bozeman, Montana, 21 pp. + tables and maps.
- Georgakakos, A., P. Fleming, M. Dettinger, C. Peters-Lidard, Terese (T.C.) Richmond, K. Reckhow, K. White, and D. Yates. 2014: Ch. 3: Water Resources. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 69-112. doi:10.7930/J0G44N6T. <http://nca2014.globalchange.gov/report/sectors/water>.
- Gibeau, M. L. and K. Heuer. 1996. Effects of transportation corridors on large carnivores in the Bow River Valley, Alberta. Pages 67-79 In Proc. Florida Department of Transportation/ Federal Highway Administration Transportation-Related Wildlife Mortality Seminar. Orlando, Florida. <https://trid.trb.org/view.aspx?id=475850>.
- Gigliotti, L. C. 2016. Ecology, habitat use, and winter thermal dynamics of snowshoe hares in Pennsylvania. M. S. Thesis, The Pennsylvania State University College of Agricultural Sciences, State College, PA. xi + 89 pp.
- Gillett, N. P., A. J. Weaver, F. W. Zwiers, and M. D. Flannigan. 2004. Detecting the effect of climate change on Canadian forest fires. *Geophysical Research Letters* 31:L18211.
- Glick, P., B. A. Stein, and N. A. Edelson, editors. 2011. *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment*. National Wildlife Federation, Washington, D.C. 168 pp.

- Goldblum, D. and L. S. Rigg. 2005. Tree growth response to climate change at the deciduous–boreal forest ecotone, Ontario, Canada. *Canadian Journal of Forest Research* 35:2709-2718.
- Gompper, M. E. 2002. Top carnivores in the suburbs? Ecological and conservation issues raised by colonization of Northeastern North America by coyotes. *Bioscience* 52(2):185-190.
- Gonzalez, P., R. P. Neilson, K. S. McKelvey, J. M. Lenihan, and R. J. Drapek. 2007. Potential impacts of climate change on habitat and conservation priority areas for *Lynx canadensis* (Canada lynx). Report to the Forest Service, U.S. Department of Agriculture, Washington D.C., and NatureServe, Arlington, Virginia. 19 pp.
- Gonzales, P., R. P. Neilson, J. M. Lenihan, and R. J. Drapek. 2010. Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. *Global Ecology and Biogeography* 19:755-768.
- Goodrich, J. M. and S. W. Buskirk. 1995. Control of abundant native vertebrates for conservation of endangered species. *Conserv. Bio.* 9:1357-1364.
- Grafius, D.R., G.P. Malanson, and D. Weiss. 2012. Secondary controls of alpine treeline elevations in the western USA. *Physical Geography* 33:146-164.
- Gray, D. R. 2008. The relationship between climate and outbreak characteristics of the spruce budworm in eastern Canada. *Climate Change* 87:361-383.
- Gregory, J. M. and J. F. B. Mitchell. 1995. Simulation of daily variability of surface temperature and precipitation in the current and 2xCO₂ climates of the UKMO climate model. *Q. J. R. Meteorol. Soc.* 121:1451–1476.
- Gregory, J. M., J. F. B. Mitchell, and A. J. Brady. 1997. Summer drought in northern midlatitudes in a time-dependent CO₂ climate experiment. *Journal of Climate* 10:662-686.
- Griffin, P. C. 2004. Landscape ecology of snowshoe hares in Montana. Ph.D. dissertation, University of Montana, Missoula. 160 pp.
- Griffin, P. C. and L. S. Mills. 2004. Snowshoe hares (*Lepus americanus*) in the western United States: movement in a dynamic landscape. Pages 438–449 in H.R. Akcakaya, M.A. Burgman, O. Kindvall, C.C. Wood, P. Sjogren-Gulve, J.S. Hatfield, and M.A. McCarthy, editors. *Species conservation and management: Case studies*. Oxford University Press, New York, New York, USA.
- Griffin, P. C. and L. S. Mills. 2007. Precommercial thinning reduces snowshoe hare abundance in the short term. *Journal of Wildlife Management* 71:559-564.
- Griffin, P. C. and L. S. Mills. 2009. Sinks without borders: snowshoe hare dynamics in a complex landscape. *Oikos* 118:1487-1498.
- Grilo, C., J. A. Bissonette, and M. Santos-Reis. 2009. Spatial–temporal patterns in Mediterranean carnivore road casualties: consequences for mitigation. *Biological Conservation* 142:301-313.

- Groffman, P. M., P. Kareiva, S. Carter, N. B. Grimm, J. Lawler, M. Mack, V. Matzek, and H. Tallis, 2014: Ch. 8: Ecosystems, Biodiversity, and Ecosystem Services. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 195-219. doi:10.7930/J0TD9V7H.
<http://nca2014.globalchange.gov/report/sectors/ecosystems>.
- Groisman, P. Y., T. R. Karl, and R. W. Knight. 1994a. Changes in snow cover, temperature, and radiative heat balance over the Northern Hemisphere. *Journal of Climate* 7:1633-1656.
- Groisman, P. Y., T. R. Karl, and R. W. Knight. 1994b. Observed impact of snow cover on the heat balance and rise of continental spring temperatures. *Science* 263:198-200.
- Gunderson 1978. A mid-continent irruption of Canada lynx, 1962-63. *Prairie Naturalist* 10:71-80.
- Hagan, J. M., L. C. Irland, and A. A. Whitman. 2005. Changing timberland ownership in the northern forest and implications for biodiversity. Manomet Center for Conservation Sciences, Forest Conservation Program, Report #MCCS-FCP-2005-1.
- Halfpenny, J. C. and G. C. Miller. 1980. History and status of Canada lynx in Colorado. Colorado Div. of Wildlife. 1980 Wildlife Research Report. 11 pp.
- Halfpenny, J. C. and G. C. Miller. 1981. History and status of Canada lynx in Colorado. Colorado Div. of Wildlife. 1981 Wildlife Research Report. 11 pp.
- Halfpenny, J. C., S. J. Bissell and D. M. Nead. 1982. Lynx verification program: history and status of the lynx in Colorado and its distributional ecology for western North America. Unpubl. Man. 23 pp.
- Hall, M. H. P. and D. B. Fagre. 2003. Modeled climate-induced glacier change in Glacier National Park, 1850-2100. *Bioscience* 53:131-140.
- Hamlet, A. F. and D. P. Lettenmaier. 1999. Effects of climate change on hydrology and water resources in the Columbia River Basin. *Journal of the American Water Resources Association* 35:1597-1623.
- Hansen, A.J., R. Rasker, B. Maxwell, J. J. Rotella, A. Wright, U. Langner, W. Cohen, R. Lawrence, and J. Johnson. 2002. Ecology and socioeconomics in the new west: a case study from Greater Yellowstone. *BioScience* 52:151-168.
- Hansen, J., M. Sato, R. Ruedy, K. Lo, D. W. Lea, and M. Medina-Elzade. 2006. Global temperature change. *PNAS* 103:14288-14293.
- Hanski, I. and M. Gilpin. 1991. Metapopulation dynamics: brief history and conceptual domain. *Biological Journal of the Linnean Society* 42:3-16.
- Hanson, K., and R. Moen. 2008. Diet of Canada Lynx in Minnesota Estimated from Scat Analysis. Department of Biology University of Minnesota Duluth. NRRI, Duluth, MN.
- Hanvey, G. 2016. Personal communication re: WY/GYA lynx questions; electronic mail to J. Zelenak, USFWS, Helena, MT, Feb. 11, 2016.

- Harper, S. C., L. L. Falk, and E. W. Rankin. 1990. The northern forest lands study of New England and New York. USDA Forest Service. Rutland, Vermont, USA.
- Harrison, D. J. 2017. External peer review of: Species status assessment for the Canada lynx (*Lynx canadensis*) contiguous United States Distinct Population Segment, Version 1.0 – Draft. 29 pp.
- Harrison, D. J., S. Morano, and S. Olson. 2016. Relationships among forest harvesting, snowshoe hares, and Canada lynx in Maine. Pages 51-56 *In* Roth, B.E. (Editor). 2016. Cooperative Forestry Research Unit: 2015 Annual Report. University of Maine. Orono. 83 pp. <http://umaine.edu/cfru/files/2016/08/2015-CFRU-Annual-Report.pdf>.
- Hartmann, D.L., A.M.G. Klein Tank, M. Rusticucci, L.V. Alexander, S. Brönnimann, Y. Charabi, F.J. Dentener, E.J. Dlugokencky, D.R. Easterling, A. Kaplan, B.J. Soden, P.W. Thorne, M. Wild and P.M. Zhai, 2013: Observations: Atmosphere and Surface. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter02_FINAL.pdf.
- Harvell, C. D., C. E. Mitchell, J. R. Ward, S. Altizer, A. P. Dobson, R. S. Ostfeld, and M. D. Samuel. 2002. Climate warming and disease risks for terrestrial and marine biota. *Neuroscience* 296:2158-2162.
- Harvel, D., S. Altizer, I. M. Cattadori, L. Harrington, and E. Weil. 2009. Climate change and wildlife diseases: when does the host matter the most? *Ecology* 90:912-920.
- Harvey, B. J., D. C. Donato, and M. G. Turner. 2016. Drivers and trends in landscape patterns of stand-replacing fire in forests of the US Northern Rocky Mountains (1984–2010). *Landscape Ecol.* DOI 10.1007/s10980-016-0408-4.
- Hatler, D. F. and A. M. M. Beal. 2003. British Columbia furbearer management guidelines, Lynx (*Lynx canadensis*). 11 pp.
- Hayhoe, K., C. P. Wake, T. G. Huntington, L. Luo, M. D. Schwartz, J., S. Sheffield, E. Wood, B. Anderson, J. Bradbury, A. DeGaetano, T. J. Troy, and D. Wolfe. 2006. Past and future changes in climate and hydrological indicators in the U.S. Northeast. 2006 Climate Dynamics DOI 10.1007/s00382-006-0187-8. 32 pp.
- Haynes, R.H., tech. coord. 2003. An analysis of the timber situation in the United States: 1952 to 2050. Gen. Tech. Rep. PNW-560. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 254 pp.
- Heilman, G. E., J. R. Strittholt, N. C. Slosser, and D. A. Dellasala. 2002. Forest fragmentation of the conterminous United States: Assessing forest intactness through road density and spatial characteristics. *Bioscience* 52:411-422.
- Heinselman, M. 1996. The Boundary Waters wilderness ecosystem. University of Minnesota Press, Minneapolis.

- Hessburg, P. F., J. K. Agee, and J. F. Franklin. 2005. Dry forests and wildland fires of the inland Northwest USA: Con-trasting the landscape ecology of the pre-settlement and modern eras. *Forest Ecology and Management*. 211:117–139.
- Hjeljord, O., V. Sahlgaard, E. Enge, M. Eggestad, and S. Gronwold. 1988. Glyphosate application in forest- ecological aspects. VII. The effect on mountain hare (*Lepus timidus*) use of a forest plantation. *Scandinavian Journal of Forest Research* 3:123-127.
- Hodges, K. E. 2000a. Ecology of snowshoe hares in southern boreal and montane forests. Pages 163-206 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). *Ecology and conservation of lynx in the contiguous United States*. University Press of Colorado, Boulder, Colorado.
- Hodges, K. E. 2000b. Ecology of snowshoe hares in northern boreal forests. Pages 117-162 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). *Ecology and conservation of lynx in the contiguous United States*. University Press of Colorado, Boulder, Colorado.
- Hodges, K. E., L. S. Mills, and K. M. Murphy. 2009. Distribution and abundance of snowshoe hares in Yellowstone National Park. *Journal of Mammalogy* 90:870-878.
- Hodgkins, G. A. and R. W. Dudley. 2006. Changes in late-winter snowpack, depth, water equivalent and density in Maine, 1926-2004. *Hydrological Processes* 20:741-751.
- Hogg, E. H. 1994. Climate and the southern limit of the western Canadian boreal forest. *Canadian Journal of Forest Research* 24:1835-1845.
- Holbrook, J. D., J. R. Squires, L. E. Olson, N. J. DeCesare, and R. L. Lawrence. 2017. Understanding and predicting habitat for wildlife conservation: the case of Canada lynx at the range periphery. *Ecosphere* 8(9):1-25. e01939.10.1002/ecs2.1939. <http://onlinelibrary.wiley.com/doi/10.1002/ecs2.1939/full>.
- Homyack, J. A. 2003. Effects of precommercial thinning on snowshoe hares, small mammals, and forest structure in northern Maine. M.S. Thesis, University of Maine, Orono. 196 pp.
- Homyack, J. A., D. J. Harrison, and W. B. Krohn. 2004. Structural differences between precommercially thinned and unthinned conifer stands. *Forest Ecology and Management* 194:131-141.
- Homyack, J. A., D. J. Harrison, and W. B. Krohn. 2005. Long-term effects of precommercial thinning on small mammals in northern Maine. *Forest Ecology and Management* 205:43–57.
- Homyack, J. A., D. J. Harrison, J. A. Litvaitis, and W. B. Krohn. 2006. Quantifying densities of snowshoe hares in Maine using pellet plots. *Wildlife Society Bulletin* 34:74-80.
- Homyack, J. A., D. J. Harrison, and W. B. Krohn. 2007. Effects of precommercial thinning on snowshoe hares in Maine. *Journal of Wildlife Management* 71:4-13.
- Homyack, J. A., J. H. Vashon, C. Libby, E. L. Lindquist, S. Loch, D. F. McAlpine, K. L. Pilgrim, and M. K. Schwartz. 2008. Canada lynx-bobcat (*Lynx canadensis* × *L. rufus*) hybrids at

- the southern periphery of lynx range in Maine, Minnesota and New Brunswick. *The American Midland Naturalist* 159:504-508.
- Hone, J., C. J. Krebs, and M. O'Donoghue. 2011. Is the relationship between predator and prey abundances related to climate for lynx and snowshoe hares. *Wildlife research* 38:419-425.
- Hornseth, M. L., A. A. Walpole, L. R. Walton, J. Bowman, J. C. Ray, M. J. Fortin, and D. L. Murray. 2014. Habitat loss, not fragmentation, drives occurrence patterns of Canada lynx at the southern range periphery. *PloS one*, 9(11), e113511.
- Horton, R., G. Yohe, W. Easterling, R. Kates, M. Ruth, E. Sussman, A. Whelchel, D. Wolfe, and F. Lipschultz. 2014. Ch. 16: Northeast. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 16-1-nn. <http://nca2014.globalchange.gov/report/regions/northeast>.
- Hoving, C. L. 2001. Historical occurrence and habitat ecology of Canada lynx (*Lynx canadensis*) in eastern North America. M.S. Thesis, University of Maine, Orono. 200 pp.
- Hoving, C. L., R. A. Joseph, and W. B. Krohn. 2003. Recent and historical distributions of Canada lynx in Maine and the Northeast. *Northeastern Naturalist* 10:363-382.
- Hoving, C. L., D. J. Harrison, W. B. Krohn, W. B. Jakubas, and M. A. McCollough. 2004. Canada lynx *Lynx canadensis* habitat and forest succession in northern Maine, USA. *Wildlife Biology* 10:285-294.
- Hoving, C. L., D. J. Harrison, W. B. Krohn, R. A. Joseph, and M. O'Brien. 2005. Broad-scale predictors of Canada lynx occurrence in eastern North America. *Journal of Wildlife Management* 69:739-751.
- Hubbart, J. A., T. E. Link, and J. A. Gravelle. 2015. Forest canopy reduction and snowpack dynamics in a northern Idaho watershed of the Continental-Maritime region, United States. *Forest Science* 61:882-894.
- Huntington, T.G. 2005. Assessment of calcium status in Maine forests; review and future projections. *Can. J. For. Res.* 35:1109-1121. Doi:10.1139/x05-034.
- Huntington, T. G., G. A. Hodgkins, B. D. Keim, and R. W. Dudley. 2004. Changes in the proportion of precipitation occurring as snow in New England (1949-2000). *Journal of Climate* 17:2626-2636.
- IDFG. 2017a. Idaho Department of Fish and Game comments re: Species Status Assessment for the Canada lynx (*Lynx canadensis*) – Draft Report Version 1.0.
- IDFG. 2017b. Idaho Department of Fish and Game, Upland Game, Furbearer & Turkey 2016-2017 Seasons and Rules. <https://idfg.idaho.gov/rules>.
- Ims, R. A., J.-A. Henden, and S. T. Killengreen. 2008. Collapsing population cycles. *Trends in Ecology and Evolution* 23:79-86.

- Interagency Lynx Biology Team (ILBT). 2013. Canada lynx conservation assessment and strategy. 3rd edition. USDA Forest Service, USDI Fish and Wildlife Service, USDI Bureau of Land Management, and USDI National Park Service. Forest Service Publication #R1-13-19, Missoula, MT. 128 pp.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R. K., and A. Reisinger (eds.)]. IPCC, Geneva, Switzerland, 104 pp. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf.
- IPCC. 2014a. Summary for policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, and L. L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32. http://ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf.
- IPCC. 2014b. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf.
- Ippoliti, J. and K. Nadeau-Drillen. 2006. Maine Office of Policy and Legal Analysis staff study of forest ownership trends and issues. Maine State Legislature; Office of Policy and Legal Analysis, Augusta, Maine. Office of Policy and Legal Analysis. Paper 153. http://digitalmaine.com/opla_docs/153.
- Irland, L. C. 2000. Ice storms and forest impacts. *The Science of the total Environment* 262:231-242.
- Irland, L. C., D. Adams, R. Alig, C. J. Betz, C. C. Chen, M. Hutchins, B. McCarl, K. Skog, and B. L. Sohngen. 2001. Assessing socioeconomic impacts of climate change on US forests, wood-product markets, and forest recreation. *BioScience* 51:753-764.
- ITIS. 2016. Integrated Taxonomic Information System online database, <http://www.itis.gov>.
- Ivan, J. S. 2011a. Density, demography, and seasonal movements of snowshoe hares in central Colorado. Ph.D. dissertation, Colorado State University, Fort Collins. 141 pp.
- Ivan, J. S. 2011b. Monitoring Canada lynx in Colorado using occupancy estimation: Initial implementation in the Core Lynx Release Area. Pages 11-20 in: *Wildlife research reports July 2010-June 2011*. Colorado Division of Parks and Wildlife, Fort Collins, Colorado. 296 pp.
- Ivan, J. S. 2011c. Putative Canada lynx (*Lynx canadensis*) movements across Hwy 50 near Monarch Ski Area. Colorado Division of Wildlife, Fort Collins. 6 pp.

- Ivan, J. S. 2011d. Putative Canada lynx (*Lynx canadensis*) movements across Hwy 114 near North Pass, Colorado. Colorado Division of Wildlife, Fort Collins. 6 pp.
- Ivan, J. S. 2011e. Predicted lynx habitat in Colorado. Pages 21-35 in: Wildlife research reports July 2010-June 2011. Colorado Division of Parks and Wildlife, Fort Collins, Colorado. 296 pp.
- Ivan, J. S. 2012. Putative Canada lynx (*Lynx canadensis*) movements across Hwy 40 near Berthoud Pass, Colorado. Colorado Division of Wildlife, Fort Collins. 5 pp.
- Ivan, J. S. 2016a. Personal communication re: WY/GYA lynx questions; electronic mail reply to J. Zelenak, USFWS, Helena, MT, February 10, 2016.
- Ivan, J. S. 2016b. Personal communication re: Information on lynx kitten survival; electronic mail reply to K. Broderdorp, USFWS, Grand Junction, CO, March 9, 2016.
- Ivan, J. S. 2017. Summary of movements of Colorado lynx in Wyoming. Colorado Parks and Wildlife, Fort Collins, CO. 36 pp.
- Ivan, J. S., M. Rice, P.M. Lukacs, T. M. Shenk, D. M. Theobald, and E. Odell. 2011. Predicted lynx habitat in Colorado. Pages 21-35 in Wildlife Research Report - Mammals. Fort Collins, CO, USA. Colorado Parks and Wildlife.
- Ivan, J. S., G. C. White, and T. M. Schenk. 2014. Density and demography of snowshoe hares in central Colorado. *The Journal of Wildlife Management* 78:580-594.
- Ivan, J. S., E. Odell, and S. Wait. 2015. Wildlife research project summary: Canada lynx monitoring in Colorado. Colorado Parks and Wildlife, Fort Collins, CO. 4 pp.
- Iverson, L. R. and A. M. Prasad. 2001. Potential changes in tree species richness and forest community types following climate change. *Ecosystems* 4:186-199.
- Iverson, L. R., A. M. Prasad, B. J. Hale, and E. K. Sutherland. 1999. An atlas of current and potential future distributions of common trees of the eastern United States. General Technical Report NE- 265, Northeastern Research Station, USDA Forest Service, Newtown Square, PA.
- Iverson, L. R., A. M. Prasad, S. N. Matthews, and M. Peters. 2008. Estimating potential habitat for 134 eastern US tree species under six climate scenarios. *Forest Ecology and Management* 254:390-406.
- Jacobson, G. L., I. J. Fernandez, P. A. Mayewski, and C. V. Schmitt (editors). 2009. *Maine's Climate Future: An Initial Assessment*. Orono, ME: University of Maine. Revised April 2009. http://climatechange.umaine.edu/files/Maines_Climate_Future.pdf.
- Jin, S. and S. A. Sader. 2006. Effects of forest ownership and change on forest harvest rates, types and trends in northern Maine. *Forest Ecology and Management* 228:177-186.
- Johnson, A. H., E. R. Cook, and T. G. Siccama. 1988. Climate and red spruce growth and decline in the northern Appalachians. *Proceedings of the National Academy of Science* 85:5369-5373.

- Johnston, D. W., A. S. Friedlander, L. G. Torres, and D. M. Lavigne. 2005. Variation in sea ice cover on the east coast of Canada from 1969 to 2002: climate variability and implications for harp and hooded seals. *Climate Research* 29:209-222.
- Johnston, K. M., K. A. Freund, and O. J. Schmitz. 2012. Projected range shifting by montane mammals under climate change: implications for Cascadia's National Parks. *Ecosphere* 3(11):97. 17 pp. <http://dx.doi.org/10.1890/ES12-00077.1>.
- Jolly, W. M., M. A. Cochrane, P. H. Freeborn, Z. A. Holden, T. J. Brown, G. J. Williamson, and D. M. J. S. Bowman. 2015. Climate-induced variations in global wildfire danger from 1979 to 2013. *Nature Communications* 6:7537. DOI: 10.1038/ncomms8537. <http://www.nature.com/naturecommunications>.
- Jones, K.R., and N.D. Mulhern. 1998. An evaluation of the severity of the January 1998 ice storm in northern New England. US Army Corps of Engineers. Cold Regions Research and Engineering Laboratory Report for FEMA, Region 1. 66 p.
- Joos, F., I. C. Prentice, S. sitch, R. Meyer, G. Hooss, G. K. Plattner, S. Gerber, and K. Hasselmann. 2001. Global warming feedbacks on terrestrial carbon uptake under the Intergovernmental Panel on climate change (IPCC) emission scenarios. *Global Biogeochemical cycles* 4:891-907.
- Joyce, L. A., J. R. Mills, L. S. Heath, A. D. McGuire, R. W. Haynes, and R. A Birdsey. 1995. Forest sector impacts from changes in forest productivity under climate change. *Journal of Biogeography* 22:703-713.
- Joyce, L. A., S. W. Running, D. D. Breshears, V. H. Dale, R. W. Malmshemer, R. N. Sampson, B. Sohngen, and C. W. Woodall. 2014. Ch. 7: Forests. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 175-194. doi:10.7930/J0Z60KZC. <http://nca2014.globalchange.gov/report/sectors/forests>.
- Judd, R. W. 2007. The Maine Woods: A Legacy of Controversy. *Maine Policy Review* 16.2:8-10. <http://digitalcommons.library.umaine.edu/mpr/vol16/iss2/3>.
- Kapfer, P. M. 2012. Bobcat (*Lynx rufus*) spatial ecology and harvest in Minnesota. Dissertation. University of Minnesota. 107pp.
- Kapnick, S., and A. Hall. 2012. Causes of recent changes in western North American snowpack. *Climate Dynamics* 38(9–10), 1885–1899, doi: 10.1007/s00382-011-1089-y.
- Karl, T. R., R. W. Knight, K. P. Gallo, T. C. Peterson, P. D. Jones, G. Kukla, N. Plummer, V. Razuvayev, J. Lindsey, and R. J. Charlson. 1993. A new perspective on recent global warming: asymmetric trends of daily maximum and minimum temperature. *Bull. Am. Meteorol Soc.* 74:1007-1023.
- Kart, J., R. Regan, S. R. Darling, C. Alexander, K. Cox, M. Ferguson, S. Parren, K. Royar, and B. Popp, editors. 2005. Vermont's Wildlife Action Plan. Vermont Fish & Wildlife Department. Waterbury, Vermont. www.vtfishandwildlife.com.

- Kasischke, E. S. and M. R. Turetsky. 2006. Recent changes in the fire regime across the North American boreal region – Spatial and temporal patterns of burning across Canada and Alaska. *Geophysical Research Letters* 33:L09703.
- Keith, J. S., D. J. Smith, and J. K. Morris. 1993. Dynamics of snowshoe hare population in fragmented habitat. *Can. J. Zool.* 71:1385–1392.
- Keane, R.E., M. F. Mahalovich, B. L. Bollenbacher, M. E. Manning, R. A. Loehman, T. B. Jain, L. M. Holsinger, A. J. Larson, and M. M. Webster. *In press*. Climate change effects on forest vegetation in the Northern Rocky Mountains. Ch. 6 in Halofsky *et al.*, eds., *Climate change vulnerability and adaptation in the Northern Rocky Mountains*. Gen. Tech. Rep. RMRS-GTR-xxx. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 881 pp.
- Kearney, M. S. and R. H. Luckmann. 1983. Post-glacial vegetational history of Tonquin Pass, British Columbia. *Canadian Journal of Earth Sciences* 20:776-786.
- Keegan, C. E., C. B. Sorenson, T. A. Morgan, S. W. Hayes, and J. M. Daniels. 2011. Impact of the great recession and housing collapse on the forest products industry in the western United States. *Forest Products Journal* 61:625-634.
- Khidas, K., J. Duhaime, and H. M. Huynh. 2013. Morphological divergence of continental and island populations of Canada lynx. *Northeastern Naturalist*, 20(4):587-608.
- Kiehl, J. T. and P. R. Gent. 2004. The Community Climate System Model, Version 2. *Journal of Climate* 17:3666-3682.
- Kilborn, J. 2015. Canada lynx (*Lynx canadensis*) in New Hampshire Wildlife Action Plan. New Hampshire Fish and Wildlife. <http://www.wildlife.state.nh.us/wildlife/wap.html>.
- Kilgore, B. M. and M. L. Heinselman. 1990. Fire in wilderness ecosystems. Pages 297–335 in Hendee, J. C., G. H. Stankey, and R. C. Lucas editors. *Wilderness management*. 2nd Edition. North American Press, Golden, Colorado, USA.
- Klos, P. Z., T. E. Link, and J. T. Abatzoglou. 2014. Extent of the rain-snow transition zone in the western U.S. under historic and projected climate. *Geophysical Research Letters* 41:4560-4568.
- Knowles, N., M. D. Dettinger, and D. R. Cayan. 2006. Trends in snowfall versus rainfall in the western United States. *Journal of Climate* 19:4545-4559.
- Koch, P. 1996. Lodgepole pine commercial forests: An essay comparing the natural cycle of insect kill and subsequent wildfire with management for utilization and wildlife. Forest Service general technical report PB--97-104236/XAB; FSGTR/INT--342 TRN: 63172348
- Koehler, G. M. 1990a. Population and habitat characteristics of lynx and snowshoe hares in north central Washington. *Canadian Journal of Zoology* 68:845-851.
- Koehler, G. M. 1990b. Snowshoe hare, *Lepus americanus*, use of forest successional stages and population changes during 1985-1989 in north-central Washington. *Canadian Field Naturalist* 105:291-293.

- Koehler, G. M. and J. D. Brittell. 1990. Managing spruce-fir habitats for lynx and snowshoe hares. *Journal of Forestry* 88:10-14.
- Koehler, G. M. and K. B. Aubry. 1994. Lynx. Pages 74-98 *in* Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, (eds.). *The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the Western United States*. USDA Forest Service Gen. Tech. Rep. RM-254.
- Koehler, G. M. and B. T. Maletzke. 2006. Lynx in the state of Washington. *Wild Cat News* 2:1-4.
- Koehler, G. M., M. G. Hornocker, and H. S. Hash. 1979. Lynx movements and habitat use in Montana. *Canadian Field-Naturalist* 93:441-442.
- Koehler, G. M., B. T. Maletzke, J. A. Von Kienast, K. B. Aubry, R. B. Wielgus, and R. H. Naney. 2008. Habitat fragmentation and the persistence of lynx populations in Washington state. *Journal of Wildlife Management* 72:1518-1524.
- Koen, E. L., J. Bowman, D. L. Murray, and P. J. Wilson. 2014a. Climate change reduces genetic diversity of Canada lynx at the trailing range edge. *Ecography* 37:754-762.
- Koen, E. L., J. Bowman, J. L. Lalor, and P. J. Wilson. 2014b. Continental-scale assessment of the hybrid zone between bobcat and Canada lynx. *Biological Conservation* 178:107-115.
- Koen, E. L., J. Bowman, and P. J. Wilson. 2015. Isolation of peripheral populations of Canada lynx (*Lynx canadensis*). *Canadian Journal of Zoology* 93:521-530.
- Kolbe, J. A. and J. R. Squires. 2006. A longevity record for Canada lynx, *Lynx canadensis*, in western Montana. *Western North American Naturalist* 66:535-536.
- Kolbe, J. A., J. R. Squires, D. H. Pletscher, and L. F. Ruggiero. 2007. The effect of snowmobile trails on coyote movements within lynx home ranges. *Journal of Wildlife Management* 71:1409-1418.
- Kosterman, M. K. 2014. Correlates of Canada lynx reproductive success in northwestern Montana. M.S. Thesis, University of Montana, Missoula. ix + 69 pp.
- Kramer-Schadt, S., E. Revilla, and T. Wiegand. 2005. Lynx reintroductions in fragmented landscapes of Germany: Projects with a future or misunderstood wildlife conservation? *Biological Conservation* 125:169-182.
- Krawchuk, M. A., S. G. Cumming, and M. D. Flannigan. 2009. Predicted changes in fire weather suggest increases in lightning fire initiation and future areas burned in the mixedwood boreal forest. *Climatic Change* 92:83-97.
- Krebs, C. J. R. Boonstra, S. Boutine, and A. R. E. Sinclair. 2001. What drives the 10-year cycle of snowshoe hares? *BioScience* 25:25-35.
- Krebs, C. J. 2011. Of lemmings and snowshoe hares: the ecology of northern Canada. *Proceedings of the Royal Society of London B* 278:481-489.

- Krebs, C. J., K. Kielland, J. Bryant, M. O'Donoghue, F. Doyle, C. McIntyre, D. DiFolco, N. Berg, S. Carriere, R. Boonstra, S. Boutin, A. J. Kenney, D. G. Reid, K. Bodony, J. Putera, H. K. Timm, and T. Burke. 2013. Synchrony in the snowshoe hare (*Lepus americanus*) cycle in northwestern North America, 1970–2012. *Canadian Journal of Zoology* 91:562-572.
- Krebs, C. J., J. Bryant, K. Kielland, M. O'Donoghue, F. Doyle, S. Carriere, D. DiFolco, N. Berg, R. Boonstra, S. Boutin, A. J. Kenney, D. G. Reid, K. Bodony, J. Putera, H. K. Timm, T. Burke, J. A. K. Maier, and H. Golden. 2014. What factors determine cyclic amplitude in the snowshoe hare (*Lepus americanus*) cycle? *Canadian Journal of Zoology* 92:1039-1048.
- Kreyling, J., A. Schmiedinge, E. Macdonald, and C. Beierkuhnlein. 2008. Slow understory redevelopment after clearcutting in high mountain forests. *Biodiversity Conservation* 17:2339-2355. DOI 10.1007/s10531-008-9385-5.
- Krohn, W. B. and C. L. Hoving. 2010. Early Maine wildlife. Historical accounts of Canada lynx, moose, mountain lion, white-tailed deer, wolverine, wolves, and woodland caribou 1603 - 1930. The University of Maine Press, Orono, Maine.
- Krohn, W., C. Hoving, D. Harrison, D. Phillips, and H Frost. 2005. *Martes* foot-loading and snowfall patterns in eastern North America. Pages 115-131 in Harrison, D. J., A. K. Fuller, and G. Proulx (editors). *Martens and Fishers (Martes) in Human-Altered Environments: An international perspective*. Springer, U.S.A.
- Küchler, V. J. 1964. Potential natural vegetation of the conterminous United States. *American Geog. Soc. Special Publication No. 36*.
- Kuehnast, E. L., D. G. Baker, and J. A. Zandlo. 1982. Climate of Minnesota: Part X111 - Duration and depth of snow cover. Technical Bulletin 333-1982. University of Minnesota. 24 pp.
- Kullman, L. 1990. Dynamics of altitudinal tree limits in Sweden: a review. *Norwegian Journal of Geography* 44:103-116.
- Kumar, V., J. Mortelmans, J. Vercruyssen, and F. Ceulemans. 1974. Chemotherapy of helminthiasis among wild animals, lung worm infestation of *Felis (Lynx) canadensis*. *Acta Zoologica et Pathologica Antverpiensia*. (61):85-89.
- Kupfer, J. A. and D. M. Cairns. 1996. The suitability of montane ecotones as indicators of global climatic change. *Progress in Physical Geography* 20:253-272.
- Lavoie, M., P. Y. Collin, F. Lemieux, H. Jolicoeur, P. Canac-Marquis, and S. Lariviere. 2009. Understanding fluctuations in bobcat harvest at the northern limit of their range. *The Journal of wildlife Management* 73:870-875.
- Le Goff, H., M. D. Flannigan, and Y. Bergeron. 2009. Potential changes in monthly fire risk in the eastern Canadian boreal forest under future climate change. *Canadian Journal of Forest Resources* 39:2369-2380.
- Legaard, K. 2016. Kasey Legaard, School of Forest Resources, University of Maine, Personal communication to Mark McCollough, U. S. Fish and Wildlife Service, Orland, Maine.

- Legaard, K., E. Simons-Legaard, S. Sader, and J. Wilson. 2013. Evaluating the interacting effects of forest management practices and periodic spruce budworm infestation on broad-scale, long term forest productivity. Final report to the Northeastern States Research Cooperative, U.S. Department of Agriculture. Unpubl. report. School of Forest Resources, University of Maine, Orono. 17 pp.
<http://nsrcforest.org/sites/default/files/uploads/legard10full.pdf>.
- Legg, T. E. and R. G. Baker. 1980. Palynology of Pinedale sediments, Devlins Park, Boulder County, Colorado. *Arctic and Alpine Research* 12:319-333.
- Lenton, T. M., H. Held, E. Kriegler, J. W. Hall, W. Lucht, S. Rahmstorf, and H. J. Schellnhuber. 2008. Tipping elements in the Earth's climate system. *PNAS* 105:1786-1793.
- Lewis, J. C. 2016. Periodic Status Review for the Lynx. Washington Department of Fish and Wildlife, Olympia, Washington. 17 + iii pp.
- Lewis, C. W., K. E. Hodges, G. M. Koehler, and L. S. Mills. 2011. Influence of stand and landscape features on snowshoe hare abundance in fragmented forests. *Journal of Mammalogy* 92:561-567.
- Licht, D. S., R. A. Moen, D. P. Brown, M. C. Romanski, and R. A. Gitzen. 2015. The Canada lynx (*Lynx canadensis*) of Isle Royale: Over-harvest, climate change, and the extirpation of an island population. *Canadian Fieldnaturalist* 129:139–151.
- Licht, D. S., R. A. Moen, and M. Romanski. 2017. Modeling viability of a potential Canada lynx reintroduction to Isle Royale National Park. *Unpubl. Proof*. *Natural Areas Journal* 37: 500-507.
- Lieberg, A. 2017. Personal communication re: Garnets Lynx; electronic mail from Adam Lieberg, Conservation Practitioner, Swan Valley Connections, Condon, MT, to J. Zelenak, USFWS, Helena, MT, Feb. 5, 2017.
- Lienard, J., J. Harrison, and N. Strigul. 2016. US forest response to projected climate-related stress: a tolerance perspective. *Global Change Biology* 22:2875-2886.
- Liliehalm, R. J., L. C. Irland, and J. M. Hagan. 2010. Changing socio-economic conditions for private woodland protection. Pages 67-98 (Chapter 5) in S. C. Trombulak and R. F. Baldwin, eds. *Landscape-scale conservation planning*. Springer-Verlag, New York, New York, USA. 427 pp.
- Linden, D. W. 2006. Modeling current and historic habitat for Canada lynx (*Lynx canadensis*) in the Upper Peninsula of Michigan. M.S. Thesis, Michigan State University, East Lansing, MI. 153 pp.
- Littell, J. S., D. L. Peterson, K. L. Riley, Y. Liu, and C. H. Luce. 2016. A review of the relationships between drought and forest fire in the United States. *Global Change Biology*, doi: 10.1111/gcb.13275. 17 pp.
- Litvaitis, J. A. and J. P. Tash. 2005. Species profile: Canada lynx *Lynx canadensis*. Pages A-296 – A-302 in *New Hampshire Wildlife Action Plan*. New Hampshire Fish and Game

Department, Concord. <http://www.wildlife.state.nh.us/nongame/documents/canada-lynx.pdf>.

- Litvaitis, J. A., J. A. Sherburne, and J. A. Bissonette. 1985. Influence of understory characteristics on snowshoe hare habitat use and density. *Journal of Wildlife Management* 49:866-873.
- Litvaitis, J. A., J. A. Sherburne, and J. A. Bissonette. 1986. Bobcat habitat use and home range size in relation to prey density. *The Journal of Wildlife Management* 50:110-117.
- Litvaitis, J. A., D. Kingman, Jr., J. Lanier, and E. Orff. 1991. Status of lynx in New Hampshire. *Transactions of the Northeast Section of the Wildlife Society* 48:70-75.
- Livingston, W. H. 2000. Maine's spruce-fir forest after the spruce budworm epidemic. 4th Annual Munsungan Conference Proceedings: Forest Health. Maine Agricultural Experiment Station Publication Number 742.
- Lorimer, C. G. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. *Ecology* 58:139-148.
- Lorimer, C. G. and A. S. White. 2003. Scale and frequency of natural disturbance in the northeastern US: implications for early successional forest habitats and regional age distributions. *Forest Ecology and Management* 185:41-64.
- Lucht, W., S. Schaphoff, T. Erbrecht, U. Heyder, and W. Cramer. 2006. Terrestrial vegetation redistribution and carbon balance under climate change. *Carbon Balance and Management* 1:6.
- Lucid, M. K. 2016. Idaho Panhandle Forest Carnivores. Interim Progress Report. Idaho Department of Fish and Game, Boise, Idaho. 18 pp.
- Lucid, M. K., L. Robinson, and S. Ehlers. 2016. Multi-species Baseline Initiative Project Report: 2010-2014. Idaho Department of Fish and Game, Coeur d'Alene, Idaho, USA. pp. 148-203.
- Lukas J., J. Barsugli, N. Doesken, I. Rangwala, K. Wolter. 2014. Climate Change in Colorado, A Synthesis to Support Water Resources Management and Adaptation, second edition. 114 pp.
- Lute, A. C., J. T. Abatzoglou, and K. C. Hegewisch. 2015. Projected changes in snowfall extremes and interannual variability of snowfall in the western United States. *Water Resources Research* 51:960-972.
- Lyons, A. L., W. L. Gaines, J. Begley, P. H. Singleton, J. C. Lewis, B. T. Maletzke. 2016. Canada Lynx Carrying Capacity in Washington. Final Report submitted to Washington Department of Fish and Wildlife. Olympia, Washington. 31 pp.
- Lynx SSA Team 2016a. Canada Lynx Expert Elicitation Workshop - Final Report. April 18, 2016. 64 pp.

- Lynx SSA Team 2016b. Canada Lynx Expert Elicitation Workshop – Notes. Bloomington, Minn., Oct. 13-15, 2015. 19 pp.
- MacLean, D. A. and M. G. Morgan. 1983. Long term growth and yield response of young fir to manual and chemical release from shrub competition. *The Forestry Chronicle* 59:177-183.
- Maine Department of Transportation (Maine State Planning Office; Maine Department of Transportation; and RKG Associates, Inc.). 1999. Maine East-West Highway: Economic Impact Analysis-Phase I Technical Report, Baseline Conditions, 1999. State Planning Office. Paper 28.
http://digitalmaine.com/cgi/viewcontent.cgi?article=1027&context=spo_docs.
- Maine Forest Service. 1995. 1994 Silvicultural Activities Report. Maine Forest Service, Department of Conservation, Augusta, Maine.
- Maine Forest Service. 2003. 2002 Silvicultural Activities Report. Maine Forest Service, Department of Conservation, Augusta, Maine. 6 pp.
http://www.maine.gov/dacf/mfs/publications/annual_reports.html#silvi.
- Maine Forest Service. 2005. 2004 Silvicultural Activities Report. Maine Forest Service, Department of Conservation, Augusta, Maine. 6 pp.
http://www.maine.gov/dacf/mfs/publications/annual_reports.html#silvi.
- Maine Forest Service. 2007. 2006 Silvicultural Activities Report. Maine Forest Service, Department of Conservation, Augusta, Maine. 6 pp.
http://www.maine.gov/dacf/mfs/publications/annual_reports.html#silvi.
- Maine Forest Service. 2016. 2015 Silvicultural Activities Report. Department of Agriculture, Conservation, and Forestry, Augusta, Maine. 8 pp.
http://www.maine.gov/dacf/mfs/publications/annual_reports.html.
- Maine Land Use Regulation Commission. 2010. Comprehensive Land Use Plan for areas within the jurisdiction of the Maine Land Use Regulation Commission. Maine Land Use Regulation Commission, Department of Conservation, Augusta, Maine. 447 pp.
http://www.maine.gov/dacf/lupc/plans_maps_data/clup/2010_CLUP.pdf.
- Maletzke, B. T. 2004. Winter habitat selection of lynx (*Lynx canadensis*) in northern Washington. M.S. Thesis, Washington State University, Pullman. 39 pp.
- Maletzke, B. T., G. M. Koehler, R. B. Wielgus, K. B. Aubry, and M. A. Evans. 2008. Habitat conditions associated with lynx hunting behavior during winter in northern Washington. *Journal of Wildlife Management* 72:1473-1478.
- Mallet, D. G. 2014. Spatial and habitat responses of Canada lynx in Maine to a decline in snowshoe hare density. M.S. Thesis, University of Maine, Orono, Maine. 170pp.
- McAllister, K.A., R. Morgenweck, and C. Jauhola. 2000. Lynx habitat mapping direction. Interagency Lynx Steering Committee. 4 pp.

- McCann, N. P. 2006. Using pellet counts to predict snowshoe hare density, snowshoe hare habitat-use, and Canada lynx habitat-use in Minnesota. M.S. Thesis, University of Minnesota. 64 pp.
- McCann, N. P. and R. A. Moen. 2011. Mapping potential core areas for lynx (*Lynx canadensis*) using pellet counts from snowshoe hares (*Lepus americanus*) and satellite imagery. *Canadian Journal of Zoology* 89:509-516.
- McCaskill, G., W. McWilliams, C. Barnett, B. Butler, M. Hatfield, C. Kurtz, R. Morin, W. Moser, C. Perry, and C. Woodall. 2011. Maine's Forest 2008. Resour. Bull. NRS-48. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 62 pp.
- McCaskill, G. L., T. Albright, C. J. Barnett, B. J. Butler, S. J. Crocker, C. M. Kurtz, W. H. McWilliams, P. D. Miles, R. S. Morin, M. D. Nelson, R. H. Widmann, and C. W. Woodall. 2016. Maine Forests, 2013. Resource Bulletin NRS-103. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 62 pp.
- McCollough, M. A. 2007. Canada lynx habitat management guidelines for Maine. U. S. Fish and Wildlife Service Maine Field Office, Old Town, Maine. 44 pp.
- McCollough, M. A. 2016. Deterministic population simulation of the Maine Canada lynx population. *Vortex* 10.
- McCord, C. M. 1974. Selection of winter habitat by bobcats (*Lynx rufus*) on the Quabbin Reservation, Massachusetts. *Journal of Mammalogy* 55:428-437.
- McCord, C. M. and J. E. Cardoza. 1982. Bobcat and lynx. Pages 728-766 in J. A. Chapman and G. A. Feldhamer (eds.). *Wild mammals of North America biology, management and economics*. Johns Hopkins University Press, Baltimore, MD.
- McDonald, P. 2016. Personal communication; electronic mail exchange with Kurt Broderdorp, USFWS, Grand Junction, CO.
- McDonald, K. A. and J. H. Brown. 1992. Using montane mammals to model extinctions due to global change. *Conservation Biology* 6:409-415.
- McKelvey, K. S., K. B. Aubry, and Y. K. Ortega. 2000a. History and distribution of lynx in the contiguous United States. Pages 207-264 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). *Ecology and conservation of lynx in the contiguous United States*. University Press of Colorado, Boulder, Colorado.
- McKelvey, K. S., S. W. Buskirk, and C. J. Krebs. 2000b. Theoretical insights into the population viability of lynx. Pages 21-37 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). *Ecology and conservation of lynx in the contiguous United States*. University Press of Colorado, Boulder, Colorado.
- McKelvey, K. S., K. B. Aubry, J. K. Agee, S. W. Buskirk, L. F. Ruggiero, and G. M. Koehler. 2000c. Lynx conservation in an ecosystem management context. Pages 419-441 in

- Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). Ecology and conservation of lynx in the contiguous United States. University Press of Colorado, Boulder, Colorado.
- McKelvey, K. S., Y. K. Ortega, G. Koehler, K. Aubry, and D. Britnell. 2000d. Canada lynx habitat and topographic use patterns in north central Washington: a reanalysis. Pages 307-336 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). Ecology and conservation of lynx in the contiguous United States. University Press of Colorado, Boulder, Colorado.
- McKelvey, K. S., K. B. Aubry, and M. K. Schwartz. 2008. Using anecdotal occurrence data for rare or elusive species: The illusion of reality and a call for evidentiary standards. *Bioscience* 58:549-555.
- McKelvey, K. S., Copeland, J. P., Schwartz, M. K., Littell, J. S., Aubry, K. B., Squires, J. R., Parks, S. A., Elsner, M. M. and Mauger, G. S. 2011. Climate change predicted to shift wolverine distributions, connectivity, and dispersal corridors. *Ecological Applications*, 21: 2882–2897. doi:10.1890/10-2206.1
- McKenney, D. W., J. H. Pedlar, K. Lawrence, K. Campbell, and M. F. Hutchinson. 2007. Potential impacts of climate change on the distribution of North American trees. *bioScience* 57:939-948.
- McKenzie, D. Z. Gedalof, D. L. Peterson, and P. Mote. 2004. Climatic change, wildfire, and conservation. *Conservation Biology* 18:890-902.
- McLaughlin, S. B., D. J. Downing, T. J. Blasing, E. R. Cook, and H. S. Adams. 1987. An analysis of climate and competition as contributors to decline of red spruce in high elevation Appalachian forests of the eastern United States. *Oecologia* 72:487-501.
- McNab, W. H. and P. E. Avers. 1994. Ecological subregions of the United States: Section descriptions. Admin. Publication WO-WSA-5. USDA Forest Service, Washington, D.C. 267 pp.
- McNab, W. H., D. T. Cleland, J. A. Freeouf, J. Keys, J.E., G. J. Nowacki, and C. A. Carpenter, comps. 2007. Description of ecological subregions: sections of the conterminous United States. U.S. Department of Agriculture, Forest Service, Washington, DC.
- McWilliams, W. H., B. J. Butler, L. E. Caldwell, D. M. Griffith, M. L. Hoppus, K. M. Laustsen, A. J. Lister, T. W. Lister, J. W. Metzler, R. S. Morin, S. A. Sader, L. B. Stewart, J. R. Steinman, J. A. Westfall, D. A. Williams, A. Whitman, and C. W. Woodall. 2005. The forests of Maine: 2003. Resource Bulletin NE-164. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 188p.
- MDIFW. 2009. Maine endangered and threatened species listing handbook; a guide for implementing the Maine Endangered Species Act. Maine Department of Inland Fisheries and Wildlife, Augusta, Maine. 47 pp.
- MDIFW. 2011. Federally Threatened: Canada Lynx (*Lynx canadensis*). Maine Department of Inland Fisheries and Wildlife, Augusta, Maine. 3 pp.

- MDIFW. 2012. Lynx incidental capture reports (10). Unpubl. data. Maine Department of Inland Fisheries and Wildlife, Augusta, Maine. 70 pp.
- MDIFW. 2014. Incidental Take Plan for Maine's Trapping Program. https://www.fws.gov/mainefieldoffice/PDFs/20141028_Maines_Incidental_Take_Plan_for_Lynx_submitted_to_USFWS_on_10_28_14.pdf.
- MDIFW. 2015a. Maine Department of Inland Fisheries and Wildlife. 2015a. 2015 research and management report. Maine Department of Inland Fisheries and Wildlife, Bangor, Maine. http://www.maine.gov/ifw/docs/reports_research_2015.pdf.
- MDIFW. 2015b. How to avoid incidental take of lynx while trapping other furbearers; updated September 2015. Maine Department of Inland Fisheries and Wildlife, Augusta, Maine.
- MDIFW. 2016a. Summary of trapping laws, Maine 2016-17. Maine Department of Inland Fisheries and Wildlife, Augusta, Maine. 25 pp.
- MDIFW. 2016b. Compliance with Maine's Incidental Take Permit -TE48539B: 2016 Annual Report. Maine Department of Inland Fisheries and Wildlife, Augusta, Maine. 55 pp.
- MDIFW. 2017. Maine Department of Inland Fisheries and Wildlife. Review and Comments on the Draft Species Status Assessment for Canada Lynx (*Lynx canadensis*) Contiguous United States Distinct Population Segment. U.S. Fish & Wildlife Service. February 10, 2017, 20 pp.
- Meaney, C. 2002. A review of Canada lynx (*Lynx canadensis*) abundance records from Colorado in the first quarter of the 20th Century. Report to the Colorado Department of Transportation. 10 pp.
- Mech, L. D. 1973. Canadian lynx invasion of Minnesota. *Biol. Conserv.* 5:151-152.
- Mech, L. D. 1980. Age, sex, reproduction, and spatial organization of lynxes colonizing northeastern Minnesota. *Journal of Mammalogy* 61:261-267.
- MEDACF. 2014. The Forestry Rules of Maine 2014: A practical guide for foresters, loggers and woodlot owners. Maine Department of Agriculture, Conservation and Forestry, Maine Forest Service, Augusta, ME. 130 pp.
- Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.
- Meslow E. C. and L. B. Keith. 1971. A correlation analysis of weather versus snowshoe hare population parameters. *The Journal of Wildlife Management* 35:1-15.
- Miles, P.D., K. Jacobson, G. J. Brand, E. Jepsen, D. Meneguzzo, M. E. Mielke, C. Olson, C. H. Perry, R. Piva, B. T. Wilson, and C. Woodall. 2007. Minnesota's forests 1999-2003: Part A. Resour. Bull. NRS-12A. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 92 pp.

- Mills, L. S., M. Zimova, J. Oyler, S. Running, J. T. Abatzoglou, and P. M. Kukacs. 2013. Camouflage mismatch in seasonal coat color due to decreased snow duration. *PNAS* 110:7360-7365.
- Millward, A. A. and C. E. Kraft. 2004. Physical influences of landscape on a large-extent ecological disturbance: the northeastern North American ice storm of 1998. *Landscape Ecology* 19:99-111.
- MNDNR. 2013. Minnesota's list of endangered, threatened, and special concern species. Minn. Dept. Natural Resources, St. Paul, Minnesota. 18 pp.
- MNDNR. 2015. Adopted Expedited Emergency Game and Fish Rules: 6234, Lynx Management Zone. Minn. Dept. Natural Resources, St. Paul, Minnesota. 3 pp.
- MNDNR. 2016a. 2016 Minnesota Hunting and Trapping Regulations Handbook. Minn. Dept. of Natural Resources, St. Paul, Minnesota. 132 pp.
- MNDNR. 2016b. Minnesota's Forest Resources 2015. Minn. Dept. of Natural Resources, Div. of Forestry, St. Paul, Minnesota. 73 pp.
- MNDNR. 2016c. Mines & Advanced Projects of Iron Ore, Metallic Minerals, Industrial Minerals, and Selected Construction Aggregates. Minn. Dept. Natural Resources, St. Paul, Minnesota. January 2016. 1 p.
- MNFRC. 2012. Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers. Minnesota Forest Resource Council, St. Paul, Minnesota. 590pp.
- MNFRC. 2013. Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers. Minnesota Forest Resource Council, St. Paul, Minnesota. 590pp.
- MNFRC. 2014. Minnesota's Forest Management Guidelines - Quick Reference Field Guide. Minnesota Department of Natural Resources. Minnesota Forest Resource Council, St. Paul, Minnesota. 84 pp.
- Moen, R. 2009. Canada lynx in the Great Lakes Region - 2009 Annual Report. Center for Water and Environment, Natural Resources Research Institute, Duluth, Minnesota. iii + 17 pp.
- Moen, R. 2017. Peer review for the U.S. Fish and Wildlife Service's Draft Species Status Assessment for the Canada lynx. Natural Resources Research Institute, University of Minnesota Duluth. 10 pp.
- Moen, R. and C. L. Burdett. 2009. Den sites of radiocollared Canada lynx in Minnesota 2004-2007. Natural Resource Research Institute, NRRRI Technical Report No. NRRRI/TR-2009/07. 19 pp.
- Moen, R., G. Niemi, C. L. Burdett, and L. D. Mech. 2005. Canada lynx in the Great Lakes Region. Natural Resource Research Institute, NRRRI Tech. Rep. NRRRI/TR-2006-16.

- Moen, R., C. L. Burdett, and G. Niemi. 2008a. Movement and habitat use of Canada lynx during denning in Minnesota. *Journal of Wildlife Management* 72:1507-1513.
- Moen, R., G. Niemi, and C. L. Burdett. 2008b. Canada lynx in the Great Lakes Region. Natural Resource Research Institute, NRRRI Tech. Rep. NRRRI/TR-2008-14 Release 1.1. 48 pp.
- Moen, R., J. M. Rasmussen, C. L. Burdett, and K. M. Pelican. 2010a. Hematology, serum chemistry, and body mass of free-ranging and captive Canada lynx in Minnesota. *Journal of Wildlife Diseases* 46:13-22.
- Moen, R., L. Terwilliger, A. R. Dohmen, and S. C. Catton. 2010b. Habitat and road use by Canada lynx making long-distance movements. Natural Resource Research Institute, NRRRI TR-2010/02 University of Minnesota, Duluth, USA. 26 pp.
- Moen, R., S. K. Windels, and B. Hansen. 2012. Lynx habitat suitability in and near Voyageurs National Park. *Natural Areas Journal* 32:348-355.
- Mohan, J. E., R. M. Cox, and L. R. Iverson. 2009. Composition and carbon dynamics of forests in northeastern North America in a future, warmer world. *Canadian Journal of Forestry Research* 39:213-230.
- Monthey, R. W. 1986. Responses of snowshoe hares, *Lepus americanus*, to timber harvesting in northern Maine. *Canadian Field-Naturalist* 100:568–570.
- Morris, K. I. 1986. Bobcat assessment. Maine Department of Inland Fisheries and Wildlife, Bangor, Maine, United States.
- Mote, P. W. 2003a. Trends in snow water equivalent in the Pacific Northwest and their climatic causes. *Geophysical Research Letters* 30:3-1 – 3-4.
- Mote, P.W. 2003b. Trends in temperature and precipitation in the Pacific Northwest during the twentieth century. *Northwest Science* 77(4):271-282.
- Mote, P., A. Hamlet, M. Clark, and D. Lettenmaier. 2005. Declining mountain snowpack in western North America. *Bulletin of the American Meteorological Society* 86:39-49.
- Mote, P., A. Hamlet, and E. Salathe. 2008. Has spring snowpack declined in the Washington Cascades? *Hydrology and Earth System Science* 12:193–206.
- Mote, P., A. K. Snover, S. Capalbo, S. D. Eigenbrode, P. Glick, J. Littell, R. Raymond, and S. Reeder. 2014. Ch. 21: North-west. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 487-513. doi:10.7930/J04Q7RWX. <http://nca2014.globalchange.gov/report/regions/northwest>.
- Mowat, G., K. G. Poole, and M. O'Donoghue. 2000. Ecology of lynx in northern Canada and Alaska. Pages 265-306 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). *Ecology and conservation of lynx in the contiguous United States*. University Press of Colorado, Boulder, Colorado.

- MTDNRC and USFWS. 2010a. Montana Department of Natural Resources and Conservation Forested State Trust Lands Habitat Conservation Plan (MDNRC HCP), Final Environmental Impact Statement (FEIS), Vol. I. 802 pp.
http://www.fws.gov/montanafieldoffice/Endangered_Species/Habitat_Conservation_Plan_s/DNRC_HCP.html.
- MTDNRC and USFWS. 2010b. MDNRC HCP, FEIS, Vol. II. 527 pp.
http://www.fws.gov/montanafieldoffice/Endangered_Species/Habitat_Conservation_Plan_s/DNRC_HCP.html.
- MTDNRC and USFWS. 2010c. MDNRC HCP, FEIS, Vol. III. 399 pp.
http://www.fws.gov/montanafieldoffice/Endangered_Species/Habitat_Conservation_Plan_s/DNRC_HCP.html.
- MTFWP. 2015. Montana's State Wildlife Action Plan. 2015. Montana Fish, Wildlife & Parks, 1420 East Sixth Avenue, Helena, MT 59620. 441 pp.
- MTFWP. 2016. Lynx Conservation in Montana. Montana Fish, Wildlife & Parks, 1420 East Sixth Avenue, Helena, MT 59620. 10 pp.
- Murphy, K. M. 2016. Personal communication re: WY/GYA lynx questions; electronic mail to J. Zelenak, USFWS, Helena, MT, Feb. 8, 2016.
- Murphy, K. M., T. M. Potter, J. C. Halfpenny, K. A. Gunther, M. T. Jones, P. A. Lundberg, and N. D. Berg. 2006. Distribution of Canada lynx in Yellowstone National Park. *Northwest Science* 80:199-206.
- Murray, D. L. 2000. A geographic analysis of snowshoe hare population demography. *Canadian Journal of Zoology* 78:1207-1217.
- Murray, D. L. 2003. Snowshoe hare and other hares. Pp. 147-175 *in* Wild Mammals of North America. Vol II. G.A. Feldhamer and B. Thompson, eds. Johns Hopkins University Press.
- Murray, D. L. and S. Boutin. 1991. The influence of snow on lynx and coyote movements: does morphology affect behavior? *Oecologia* 88:463-469.
- Murray, D. L., S. Boutin, and M. O'Donoghue. 1994. Winter habitat selection by lynx and coyotes in relation to snowshoe hare abundance. *Can. Journal of Zool.* 72: 1444-1451.
- Murray, D. L., S. Boutin, M. O'Donoghue, and V. O. Nams. 1995. Hunting behavior of a sympatric felid and canid in relation to vegetative cover. *Anim. Behav.* 50:1203-1210.
- Murray, D. L., T. D. Steury, and J. D. Roth. 2008. Assessment of Canada Lynx research and conservation needs in the southern range: another kick at the cat. *Journal of Wildlife Management* 72:1463-1472.
- Nagorsen, D. W. 1983. Winter pelage colour in snowshoe hares (*Lepus americanus*) from the Pacific Northwest. *Canadian Journal of Zoology* 61:2313-2318.

- National Park Service. 2002. General Management Plan - Voyageurs National Park. U.S. Dept. of the Interior, National Park Service.
- Nellis, C. H., S. P. Wetmore, and L. B. Keith. 1972. Lynx-prey interactions in central Alberta. *Journal of Wildlife Management* 36:320-328.
- NHFGD. 2017. New Hampshire Fish and Game Department comments on the Draft Canada Lynx Species Status Assessment. 2 pp.
- Ning, L. and R. S. Bradley. 2015. Winter climate extremes over the northeastern United States and southeastern Canada and teleconnections with large-scale modes of climate variability. *Journal of Climate* 28.6:2475-2493.
- NOAA (National Oceanic and Atmospheric Administration). 2007. Patterns of greenhouse warming. https://www.gfdl.noaa.gov/wp-content/uploads/files/research/climate-change/gfdlhighlight_vol1n6.pdf.
- Norton, M.R., S. J. Hannon, and F. K. A. Schmiegelow. 2000. Fragments are not islands: patch vs landscape perspectives on songbird presence and abundance in a harvested boreal forest. *Ecography* 23.2:209-223.
- Notaro, M., D. Lorenz, C. Hoving, and M. Schummer. 2014 Twenty-first-century projections of snowfall and winter severity across central-eastern North America. *Journal of Climate* 27:6526-6550.
- Notaro, M., V. Bennington, and S. Vavrus. 2015. Dynamically downscaled projections of lake-effect snow in the Great Lakes Basin. *American Meteorological Society* 28:1661-1684.
- O'Donoghue, M., S. Boutin, C. J. Krebs, and E. J. Hofer. 1997. Numerical responses of coyotes and lynx to the snowshoe hare cycle. *Oikos* 80:150-162.
- O'Donoghue, M., S. Boutin, C. J. Krebs, D. L. Murray, and E. J. Hofer. 1998. Behavioural responses of coyotes and lynx to the snowshoe hare cycle. *Oikos* 82:169-183.
- Oehler, J. D. and J. A. Litvaitis. 1996. The role of spatial scales in understanding responses of medium-sized carnivores to forest fragmentation. *Can. J. Zool.* 74:2070-2079.
- Oliver, C. D. 1980. Forest development in North America following major disturbances. *Forest Ecology and Management* 3:153-168.
- Oliver, C.D., and B. C. Larson. 1996. *Forest stand dynamics*. Updated ed. John Wiley & Sons, New York.
- Ollinger, S. V., C. L. Goodale, K. Hayhoe, and J. P. Jenkins. 2008. Potential effects of climate change and rising CO₂ on ecosystem processes in Northeastern U.S. Forests. *Mitigation and Adaptation Strategies for Global Change* 31:467-485.
- Olson, L. E., J. R. Squires, N. J. DeCesare, and J. A. Kolbe. 2011. Den use and activity patterns in female Canada lynx (*Lynx canadensis*) in the Northern Rocky Mountains. *Northwest Science* 85:455-462.

- Olson, S. J. 2015. Seasonal influences on habitat use by snowshoe hares: Implications for Canada lynx in northern Maine. M. S. Thesis, Univ. of Maine, Orono. 153 pp.
- Olson, R., R. Sriver, W. Chang, M. Haran, N. M. Urban, and K. Keller. 2013. What is the effect of unresolved internal climate variability on climate sensitivity estimates? *J. Geophys. Res. Atmos.* 118:4348–4358. doi:[10.1002/jgrd.50390](https://doi.org/10.1002/jgrd.50390).
- Organ, J. F., J. H. Vashon, J. E. McDonald, Jr., A. D. Vashon, S. M. Crowley, W. J. Jakubas, G. J. Matula, Jr., and A. L. Meehan. 2008. Within-stand selection of Canada lynx natal dens in northwest Maine, USA. *Journal of Wildlife Management* 72:1514-1517.
- Oyler, J. W., S. Z. Dobrowski, A. P. Ballantyne, A. E. Klene, and S. W. Running. 2015. Artificial amplification of warming trends across the mountains of the western United States. *Geophysical Research Letters* 42:153-161.
- Painter, T. H., A. P. Barrett, C. C. Landry, J. C. Neff, M. P. Cassidy, C. R. Lawrence, K. E. McBride, and G. L. Farmer. 2007. Impact of disturbed desert soils on duration of mountain snow cover. *Geophysical Research Letters* 34:L12502.
- Painter, T. H., D. F. Berisford, J. W. Boardman, K. J. Bormann, J. S. Deems, F. Gehrke, A. Hedrick, M. Joyce, R. Laidlaw, D. Marks, C. Mattmann, B. McGurk, P. Ramirez, M. Richardson, S. M. Skiles, F. C. Seidel, and A. Winstral. 2016. The Airborne Snow Observatory: Fusion of scanning lidar, imaging spectrometer, and physically-based modeling for mapping snow water equivalent and snow albedo. *Remote Sensing of Environment* 184:139-152.
- Parker, G. R. 1984. Use of spruce plantations by snowshoe hares in New Brunswick. *The Forestry Chronicle* 60:162-166.
- Parker, G. R. 1986. The importance of cover on use of conifer plantations by snowshoe hares in northern New Brunswick. *The Forestry Chronicle* 62:159-163.
- Parker, G. R., J. W. Maxwell, and L. D. Morton. 1983. The ecology of lynx (*Lynx canadensis*) on Cape Breton Island. *Canadian Journal of Zoology* 61:770-786.
- Passamaquoddy Tribe. 2014. Environment. http://www.passamaquoddy.com/?page_id=134.
- Patton, G. 2006. Idaho snow-track survey, Winter 2006. Unpubl. report, Idaho Department of Fish and Game, Nampa, Idaho. 31 pp.
- Payne, J. T., A. W. Wood, A. F. Hamlet, R. N. Palmer, and D. P. Lettenmaier, 2004: Mitigating the effects of climate change on the water resources of the Columbia River basin. *Climatic Change* 62:233-256.
- Pederson, G. T., S. T. Gray, C. A. Woodhouse, J. L. Betancourt, D. B. Fagre, J. S. Littell, E. Watson, B. H. Luckman, and L. J. Graumlich. 2011. The unusual nature of recent snowpack declines in the North American cordillera. *Science* 333:332-335.
- Pederson, G. T., J. L. Betancourt, and G. J. McCabe. 2013. Regional patterns and proximal causes of the recent snowpack decline in the Rocky Mountains, U.S. *Geophysical Research Letters* 40:1811-1816.

- Peers M. J. L., D. H. Thornton, and D. L. Murray. 2012. Reconsidering the specialist-generalist paradigm in niche breadth dynamics: Resource gradient selection by Canada lynx and bobcat. *PLoS ONE* 7(12): e51488. doi:10.1371/journal.pone.0051488.
- Peers, M. J. L., D. H. Thornton, and D. L. Murray. 2013. Evidence for large-scale effects of competition: niche displacement in Canada lynx and bobcat. *Proc R Soc B* 280: 20132495. <http://rspb.royalsocietypublishing.org/content/280/1773/20132495>.
- Peers, M. J. L., M. Wehtje, D. H. Thornton, and D. L. Murray. 2014. Prey switching as a means of enhancing persistence in predators at the trailing southern edge. *Global Change Biology* 20:1126–1135.
- Peng, C., Z. Ma, X. Lei, Q. Zhu, H. Chen, W. Wang, S. Liu, W. Li, X. Fang, and X. Zhou. 2011. A drought-induced pervasive increase in tree mortality across Canada's boreal forests. *Nature Climate Change* 1:467-471.
- Penobscot Indian Nation. 2012. Chapter VII Inland Fish and Game Regulations. Approved by Chief and Council, June 13, 2012. 34 pp. Accessed May 15, 2014. Revised June 4, 2016. <http://www.narf.org/nill/codes/penobscot/ch07.PDF>.
- Penobscot Indian Nation. 2014. Department of Natural Resources. Accessed May 15, 2014. Revised 2016. <https://www.penobscotnation.org/departments/natural-resourcesNaturalResources>.
- Perez-Garcia, J., L. Joyce, L., A. D. McGuire, and X. Xiao. 2002. Impacts of climate change on the global forest sector. *Climatic Change* 54:439-461.
- Peters, G. P., R. M. Andrew, T. Boden, J. G. Canadell, P. C. Ciais, C. LeQuere, G. Marland, M. R. Raupach, and C. Wilson. 2013. The challenge to keep global warming below 2°C. *Nature Climate Change* 3.1:4-6.
- Pidot, J. 2011. Conservation easement reform: As Maine goes should the nation follow? *Law and Contemporary Problems* 74:1-27.
- Pierce, D. W., T. P. Barnett, H. G. Hidalgo, T. Das, C. Bonfils, B. D. Santer, G. Bala, M. D. Dettinger, D. R. Cayan, A. Mirin, A. W. Wood, and T. Nozawa. 2008. Attribution of declining western U.S. snowpack to human effects. *Journal of Climate* 21:6425-6444.
- Pilgrim, K. 2016. Personal communication re: DNA-verified lynx in Wyoming; electronic mail reply to J. Zelenak, USFWS, Helena, MT, Sept. 8, 2016.
- Pitt, D. and L. Lanteigne. 2008. Long-term outcome of precommercial thinning in northwestern New Brunswick: growth and yield of balsam fir and red spruce. *Canadian Journal of Forest Research* 38:592-610.
- Poole, K. G. 1994. Characteristics of an unharvested lynx population during a snowshoe hare decline. *Journal of Wildlife Management* 58:608-618.
- Poole, K. G. 1997. Dispersal patterns of lynx in the Northwest Territories. *Journal of Wildlife Management* 61:497-505.

- Poole, K. G. 2003. A review of the Canada lynx, *Lynx canadensis*, in Canada. The Canadian Field Naturalist 117:360-376.
- Poole, K. G. and G. Mowat. 2001. Alberta furbearer harvest data analysis. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Report No. 31. Edmonton, AB. 51 pp.
- Pothier D. and M. Prevost. 2008. Regeneration development under shelterwoods in a lowland red spruce – balsam fir stand. Canadian Journal of Forest Research 38:31-39.
- Pozzanghera, C. B., K. J. Sivy, M. S. Lindberg, and L. R. Prugh. 2016. Variable effects of snow conditions across boreal mesocarnivore species. Can. Journal of Zoology 94:697-705.
- Prasad, A. M., L. R. Iverson., S. Matthews., M. Peters. 2007-ongoing. A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States [database]. <http://www.nrs.fs.fed.us/atlas/tree>, Northern Research Station, USDA Forest Service, Delaware, Ohio.
- Prentice, M. B., J. Bowman, K. Khidas, E. L. Koen, J. R. Row, D. L. Murray, and P. J. Wilson. 2017. Selection and drift influence genetic differentiation of insular Canada lynx (*Lynx Canadensis*) on Newfoundland and Cape Breton Island. Ecology and Evolution 2017:3281-3294.
- Price, D. T., R. I. Alfaro, K. J. Brown, M. D. Flannigan, R. A. Fleming, E. H. Hogg, M. P. Girardin, T. Lakusta, M. Johnston, D. W. McKenney, J. H. Pedlar, T. Stratton, R. N. Sturrock, I. D. Thompson, J. A. Trofymow, and L. A. Venier. 2013. Anticipating the consequences of climate change for Canada's boreal forest ecosystems. Environmental Review 21:322-365.
- Pryor, S. C., D. Scavia, C. Downer, M. Gaden, L. Iverson, R. Nordstrom, J. Patz, and G. P. Robertson. 2014. Ch. 18: Midwest. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 418-440. doi:10.7930/J0J1012N. <http://nca2014.globalchange.gov/report/regions/midwest>.
- Publicover, D. 2013. High-elevation spruce-fir forest in the northern forest: an assessment of ecological value and conservation priorities. Appalachian Mountain Club, Gorham, New Hampshire. <https://nsrforest.org/sites/default/files/uploads/publicoverfull11.pdf>.
- Public Law 95-625. (1978). National Parks and Recreation Act of 1978. 84 pp.
- Pulliam, H. R. 1988. Sources, Sinks, and Population Regulation. The American Naturalist 132:652-661.
- Qian, Y., W. I. gustafson, L. R. Leung, and S. J. Ghan. 2009. Effects of soot-induced snow albedo change on snowpack and hydrological cycle in western United States based on weather research and forecasting chemistry and regional climate simulations. Journal of Geophysical Research 114:D03108.

- Quinn, N. W. S. and G. Parker. 1987. Lynx. Pages 683-694 in M. Novak, J.A. Barber, M.E. Obbard, B. Malloch (eds.). Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources.
- Raffa, K. F., B. H. Aukema, B. J. Bentz, A. L. Carroll, J. A. Hicke, M. G. Turner, and W. H. Romme. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: the dynamics of bark beetle eruptions. *Bioscience* 58:501-517.
- Rangwala, I. and J. R. Miller. 2012. Climate change in mountains: a review of elevation-dependant warming and its possible causes. *Climate Change* 114:527-547.
- Rangwala, I., E Sinsky, and J. R. Miller. 2013. Amplified warming projections for high altitude regions of the northern hemisphere mid-latitudes from CMIP5 models. 10 pp.
- Rasouli, K., J. W. Pomeroy, and D. G. Marks. 2015. Snowpack sensitivity to perturbed climate in a cool midlatitude mountain catchment. *Hydrological Processes* 29:3925-3940.
- Ravenscroft, C., R. M. Scheller, D.J. Mladenoff, and M. A. White. 2010. Forest restoration in a mixed ownership landscape. *Ecological Applications* 20:327–346.
- Rawlins, M. A., R. S. Bradley, and H. F. Diaz. 2012. Assessment of regional climate model simulation estimates over the northeast United States, *J. Geophys. Res.*, 117, D23112, doi:[10.1029/2012JD018137](https://doi.org/10.1029/2012JD018137).
- Ray, J. C., J. E. Organ, and M. S. O'Brien. 2002. Canada lynx (*Lynx canadensis*) in the northern Appalachians: current knowledge, research priorities, and a call for regional cooperation and action. Report of a meeting held in Portland, Maine April, 2002. Wildlife Conservation Society, Toronto, Ontario, Canada. <http://carnivorecology.free.fr/pdf/WCSlynx.pdf>.
- Reeve, A., F. Lindzey, and S. Buskirk. 1986a. Historic and recent distribution of the lynx in Wyoming: Tables, figures, and appendices A-D. Wyoming Cooperative Fishery and Wildlife Research Unit, Laramie. Pp. 25-76.
- Reeve, A., F. Lindzey, and S. Buskirk. 1986b. Historic and recent distribution of the lynx in Wyoming. Wyoming Cooperative Fishery and Wildlife Research Unit, Laramie. 21 pp.
- Regniere, J., R. St-Amant, and P. Duval. 2012. Predicting insect distributions under climate change from physiological responses: spruce budworm as an example. *Biological Invasions* 14:1571-1586.
- Reichard, M. V., D. L. Caudell, and A. A. Kocan. 2004. Survey of Helminth lung parasites of bobcats (*Lynx rufus*) from Alabama, Kansas, New Mexico, Oklahoma, and Virginia, U.S.A. *Comparative Parasitology* 71:88-90.
- Reimer, J. P. 2016. Personal communication re: Lynx range - area request; electronic mail reply to J. Zelenak, USFWS, Helena, MT, May 5, 2016.
- Richardson, A.D. and A.J. Friedland. 2009. A review of the theories to explain arctic and alpine treelines around the world. *Journal of Sustainable Forestry* 28:218-242.

- Riley, K. L., J. T. Abatzoglou, I. C. Grenfell, A. E. Klene, and F. A. Heinsch. 2013. The relationship of large fire occurrence with drought and fire danger indices in the western USA, 1984–2008: the role of temporal scale. *International Journal of Wildland Fire* 22: 894–909. <http://dx.doi.org/10.1071/WF12149>.
- Rizzo, B. and E. Wiken. 1992. Assessing the sensitivity of Canada's ecosystems to climatic change. *Climatic Change* 21:37-55.
- Roberts, N. M. and S. M. Crimmins. 2010. Bobcat population status and management in North America: evidence of large-scale population increase. *Journal of Fish and Wildlife Management* 1:169-174.
- Robinson, L. 2006. Ecological relationships among partial harvesting, vegetation, snowshoe hares, and Canada lynx in Maine. M. S. Thesis, University of Maine, Orono, Maine, USA. 184 pp.
- Rodriguez, A. and M. Delibes. 2003. Population fragmentation and extinction in the Iberian lynx. *Biological Conservation* 109:321-331.
- Rojelj, J., M. Meinshausen, and R. Knutti. 2012. Global warming under old and new scenarios using IPCC climate sensitivity range estimates. *Nature Climate Change* 2:248-253.
- Rolek, B. 2016., Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono. Unpublished data from doctoral dissertation shared by Dan Harrison with Mark McCollough, USFWS, Maine Field Office on 2.29.2016.
- Rolstad, J. 1991. Consequences of forest fragmentation for the dynamics of bird populations: conceptual issues and the evidence. *Biol. Journal of the Linnean Soc.* 42.1-2:149-163.
- Romero-Lankao, P., J.B. Smith, D.J. Davidson, N.S. Diffenbaugh, P.L. Kinney, P. Kirshen, P. Kovacs, and L. Villers Ruiz, 2014: North America. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1439-1498. <http://ipcc-wg2.gov/AR5/report/graphics/Ch26>.
- Roth, J. D., J. D. Marshall, D. L. Murray, D. m. Nickerson, and T. D. Steury. 2007. Geographical gradients in diet affect population dynamics of Canada lynx. *Ecology* 88:2736–2743.
- Row, J. R., C. Gomez, E. L. Koen, J. Bowman, D. L. Murray, and P. J. Wilson. 2012. Dispersal promotes high gene flow among Canada lynx populations across mainland North America. *Conservation Genetics* 13:1259-1268.
- Rowe, J. S. 1972. Forest regions of Canada. Canadian Forestry Service, Publication 1300, Ottawa, Canada.

- Roy, C., L. Imbeau, and M. J. Mazerole. 2010. Transformation of abandoned farm fields into coniferous plantations: is there enough vegetation structure left to maintain winter habitat for snowshoe hares? *Canadian Journal of Zoology* 88:579-588.
- Ruediger, B., J. Claar, S. Gniadek, B. Holt, L. Lewis, S. Mighton, B. Naney, G. Patton, T. Rinaldi, J. Trick, A. Vandehey, F. Wahl, N. Warren, D. Wenger, and A. Williams. 2000. Canada lynx conservation assessment and strategy, second edition. USDA Forest Service, USDI Fish and Wildlife Service, USDI Bureau of Land Management, USDI National Park Service. Forest Service Publication #R1-00-53, Missoula, MT.
- Ruggiero, L. F., M. K. Schwartz, K. B. Aubry, C. J. Krebs, A. Stanley, S. W. Buskirk. 2000a. Species conservation and natural variation among populations. Pages 101-116 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). *Ecology and conservation of lynx in the contiguous United States*. University Press of Colorado, Boulder, Colorado.
- Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires. 2000b. The scientific basis for lynx conservation: qualified insights. Pages 443-454 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). *Ecology and conservation of lynx in the contiguous United States*. University Press of Colorado, Boulder, Colorado.
- Rupp, T. S., F. S. Chapin III, and A. M. Starfield. 2000. Response of subarctic vegetation to transient climatic change on the Seward Peninsula in north-west Alaska. *Global Change Biology* 6:541-555.
- Russell, M. and M. Albers. 2016. Eastern spruce budworm: Management approaches in Minnesota's forests. University of Minnesota Extension center for Agriculture, Food and Natural Resources - Forestry. University of Minnesota, Twin Cities. 4 pp.
- Rustad, L., J. Campbell, J. S. Dukes, T. Huntington, K. F. Lambert, J. Mohan, and N. Rodenhouse. 2012. Changing climate, changing forests: the impacts of climate change on forests of the Northeastern United States and Eastern Canada. General Technical Report NRS-99. Newtown Square, Pennsylvania: U. S. Department of Agriculture, Forest Service, Northern Research Station. 48pp.
- Sader, S. A., M. Bertrand, and E. H. Wilson. 2003. Satellite change detection of forest harvest patterns on an industrial forest landscape. *Forest Science* 49:341-353.
- Salathe, E. P., Jr., L. R. Leung, Y. Qian, and Y. Zhang. 2010. Regional climate model projections for the State of Washington. *Climatic Change* 102:51-75.
- Sarmiento, L. and B. D. Stough. 1956. *Troglostrongylus wilsoni* (Stough, 1953) n. comb. (Nematoda: Metastrongylidae) from the lungs of bobcat, *Lynx rufus rufus*. *The Journal of Parasitology* 42:45-48.
- Saunders, J. K., Jr. 1963. Food habits of the lynx in Newfoundland. *Journal of Wildlife Management* 27:384-390.

- Scalzitti, J., C. Strong, and A. Kochanski. 2016. Climate change impact on the roles of temperature and precipitation in western U.S. snowpack variability. *Geophysical Research Letters* 43:5361-5369.
- SCCMT. 2014. Southwestern Crown Carnivore Monitoring Team. Forest carnivore monitoring in the Southwestern Crown of the Continent: Progress Report 2012-2014. 48 pp.
- Schauffler, M. and G. L. Jacobson. 2002. Persistence of coastal spruce refugia during the Holocene in northern New England, USA, detected by stand-scale pollen stratigraphies. *Journal of Ecology* 90:235-250.
- Scheller, R. M. and D. J. Mladenoff. 2005. A spatially interactive simulation of climate change, harvesting, wind, and tree species migration and projected changes to forest composition and biomass in northern Wisconsin, USA. *Global Chan. Biol.* 11.2:307-321.
- Schindler, D. W. and P. G. Lee. 2010. Comprehensive conservation planning to protect biodiversity and ecosystem services in Canadian boreal regions under a warming climate and increasing exploitation. *Biological Conservation* 143:1571-1586.
- Schmitz, O. J., E. Post, C. E. Burns, and K. M. Johnston. 2003. Ecosystem responses to global climate change: moving beyond color mapping. *BioScience* 53:1200-1205.
- Schwartz. M. K. 2017. Peer review for the U.S. Fish and Wildlife Service's Draft Species Status Assessment for the Canada lynx. USDA Forest Service Rocky Mountain Research Station, Missoula, MT. 5 pp.
- Schwartz, M. K., L. S. Mills, K. S. McKelvey, L. F. Ruggiero, and F. W. Allendorf. 2002. DNA reveals high dispersal synchronizing the population dynamics of Canada lynx. *Nature* 415:520-522.
- Schwartz, M. K., L. S. Mills, Y. Ortega, L. F. Ruggiero, and F. W. Allendorf. 2003. Landscape location affects genetic variation of Canada lynx (*Lynx canadensis*). *Molecular Ecology* 12:1807-1816.
- Schwartz, M. K., K. L. Pilgrim, K. S. McKelvey, E. L. Lindquist, J. J. Clarr, S. Loch, and L. F. Ruggiero. 2004. Hybridization between Canada lynx and bobcats: genetic results and management implications. *Conservation Genetics* 5:349-355.
- Scott, S. A. 2009. Spatio-temporal dynamics of snowshoe hare density and relationships to Canada lynx occurrence in northern Maine. M.S. thesis. University of Maine at Orono. 190 pp.
- Settele, J., R. Scholes, R. Betts, S. Bunn, P. Leadley, D. Nepstad, J.T. Overpeck, and M.A. Taboada, 2014: Terrestrial and inland water systems. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 271-359.

- Seymour, R. S. 1992. The red spruce-balsam fir forest of Maine: Evolution of silvicultural practice in response to stand development patterns and disturbances. Pages 217-244 in *The Ecology and Silviculture of Mixed-Species Forests: A Festschrift for David M. Smith*. Kely, M.J., B.C. Larson, and C.D. Oliver (eds.). Kluwer Academic Publishers, Netherlands. 308pp.
- Seymour, R. S. and M. L. Hunter, Jr. 1992. *New forestry in eastern spruce-fir forests: principles and applications in Maine*. Maine Agricultural and Forest Experiment Station, University of Maine, Miscellaneous Publication 716, Orono, Maine, USA. 36 pp.
- Seymour, R. S., A. S. White, and P. G. deMaynadier. 2002. Natural disturbance regimes in northeastern North America - evaluating silvicultural systems using natural scales and frequencies. *Forest Ecology and Management* 155:357-367.
- Shafer, M., D. Ojima, J. M. Antle, D. Kluck, R. A. McPherson, S. Petersen, B. Scanlon, and K. Sherman. 2014. Ch. 19: Great Plains. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 441-461. doi:10.7930/J0D798BC. <http://nca2014.globalchange.gov/report/regions/great-plains>.
- Shenk, T. M. 2008. Post-release monitoring of lynx reintroduced to Colorado. Wildlife research report, July 2007–June 2008. Colorado Division of Wildlife, Fort Collins, Colorado. 25 pp.
- Shenk, T. M. 2009. Post-release monitoring of lynx reintroduced to Colorado. Wildlife research report, July 2008–August 2009. Colorado Division of Wildlife, Fort Collins, Colorado. 28 pp. + Appendices.
- Shenk, T. M. 2010. Post-release monitoring of lynx reintroduced to Colorado. Wildlife research report, July 2009–June 2010. Colorado Division of Wildlife, Fort Collins, Colorado. 26 pp.
- Siegler, H. R. and S. E. Jorgensen. 1971. The Status of wildcats in New Hampshire” *Proceedings of the Symposium on Native Cats of North America*. U.S. Bureau of Sport, Fish, and Wildlife. Portland. 139 pp.
- Sievert, P. R. and L. B. Keith. 1985. Survival of snowshoe hares at a geographic range boundary. *J. Wildl. Manage.* 49:854-866.
- Silver, H. 1957. *A history of New Hampshire game and furbearers*. New Hampshire Fish and Game Department, Concord.
- Silver, H. 1974. *A history of New Hampshire game and furbearers*. No. 6, New Hampshire Fish and Game Dept. Concord. 466 pp.
- Simons, E. M. 2009. Influences of past and future forest management on the spatiotemporal dynamics of habitat supply for Canada lynx and American martens in northern Maine. Ph.D. dissertation, University of Maine at Orono. 247 pp.
- Simons-Legaard, E.M. 2015. Erin Simons-Legaard, Assistant Research Professor in Forest Landscape Modeling, School of Forest Resources, University of Maine, Orono, Maine to Mark McCollough, U. S. Fish and Wildlife Service, Maine Field Office, Orland, Maine.

- Simons-Legaard, E. M. 2016. Modeling timber harvest and habitat uncertainty: landscape trends (2010-2060) for Canada lynx and American marten in Maine. University of Maine Report to U. S. Fish and Wildlife Service, Maine Field Office. 19 pp.
- Simons-Legaard, E. M., D. J. Harrison, and K. R. Leggaard. 2016. Habitat monitoring and projections for Canada lynx: linking the Landsat archive with carnivore occurrence and prey density. *Journal of Applied Ecology* 53:1260-1269.
- Simons-Legaard, E. M., D. J. Harrison, W. B. Krohn, and J. H. Vashon. 2013. Canada lynx occurrence and forest management in the Acadian Forest. *Journal of Wildlife Management* 77:567-578.
- Singleton, P.H., W.L.Gaines, and J.F. Lehmkuhl. 2002. Landscape permeability for large carnivores in Washington: a geographic information system weighted-distance and least-cost corridor assessment. Res. Pap. PNW-RP-549. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 89 pp.
- Siren, A. P. K. 2014a. 2012-2014 New Hampshire Fish and Game Canada Lynx Summary Report. 44 pp.
- Siren, A. P. K. 2016a. Winter 2014–2015 New Hampshire Canada lynx snow track and camera surveys. 2 pp.
- Siren, A. P. K. 2014b. A comparison of snow-track and camera surveys for detecting Canada lynx (*Lynx canadensis*) and sympatric carnivores in northcentral New England. Unpublished report emailed to Mark McCollough, USFWS on 12.23.2014.
- Siren, A. P. K. 2016b. Personal communication re: additional question or two about climate change citations; electronic mail reply to J. Zelenak, USFWS, Helena, MT, June 9, 2016.
- Siren, A., P. K. 2017. Assessing potential impacts of climate change on carnivore occupancy and snowshoe hare demography along elevational and latitudinal gradients in New England. Unpublished Report provided to the U. S. Fish and Wildlife Service, electronic mail to M. McCollough dated June 21, 2017. 33pp.
- Siren, A.P. K., A. Newell, J. R. Killborn. 2015. Influence of stand and landscape composition on snowshoe hare density and population fluctuations in the White Mountain National Forest. Unpublished Report, University of Massachusetts, Amherst, Massachusetts.
- Slough, B. G. 1999. Characteristics of Canada lynx, *Lynx canadensis*, maternal dens and denning habitat. *Canadian Field-Naturalist* 113:605-608.
- Slough, B. G. and G. Mowat. 1996. Population dynamics of lynx in a refuge and interactions between harvested and unharvested populations. *Journal of Wildlife Management* 60:946-961.
- Smith, W.K., M.J. Germino, T.E. Hancock, and D.M. Johnson. 2003. Another perspective on altitudinal limits of alpine timberlines. *Tree Physiology* 23:1101-1112.
- Sohngen, B. R. Mendelsohn, and R. Sedjo. 1998. A global model of climate change impacts on timber markets. *Journal of Agricultural and Resource Economics* 26:326-343.

- Soja, A. J., N. M. Tchebakova, N. H. F. French, M. D. Flannigan, H. H. Shugart, B. J. Stocks, A. I. Sukhinin, E. I. Parfenova, F. S. Chapin III, and P. W. Stackhouse Jr. 2007. Climate-induced boreal forest change: predictions versus current observations. National Aeronautic and Space Administration Report.
<https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20080007122.pdf>.
- Sparks, J. 2016a. Personal communication re: Garnet Questions; electronic mail reply to J. Zelenak, USFWS, Helena, MT, Feb. 3, 2016.
- Sparks, J. 2016b. Personal communication re: BLM Mgmt Plans and Lynx; electronic mail reply to J. Zelenak, USFWS, Helena, MT, June 29, 2016.
- Sprugel, D. G. 1976. Dynamic structure of wave-regenerated *Abies balsamea* forests in the north-eastern United States. *The Journal of Ecology* 64:889-911.
- Squires, J. R. 2014. Peer review of proposed critical habitat designation for the Canada lynx. January 15, 2014. 11 pp.
- Squires, J. R. 2016. Personal communication re: Garnet lynx; electronic mail reply to J. Zelenak, USFWS, Helena, MT, May 23, 2016.
- Squires, J. R. 2017. Peer review for the U.S. Fish and Wildlife Service's Draft Species Status Assessment for the Canada lynx. USDA Forest Service Rocky Mountain Research Station, Missoula, MT. 9 pp.
- Squires, J. R. and T. Laurion. 2000. Lynx home range and movements in Montana and Wyoming: preliminary results. Pages 337-349 in Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds.). *Ecology and conservation of lynx in the contiguous United States*. University Press of Colorado, Boulder, Colorado.
- Squires, J. R. and R. Oakleaf. 2005. Movements of a male Canada lynx crossing the Greater Yellowstone Area, including highways. *Northwest Science* 79:196-2001.
- Squires, J. R. and L. F. Ruggiero. 2007. Winter prey selection of Canada lynx in northwestern Montana. *Journal of Wildlife Management* 71:310-315.
- Squires, J. R., S. Tomson, L. F. Ruggiero, and B. Oakleaf. 2001. Distribution of lynx and other forest carnivores in the Wyoming Range, southcentral Wyoming. Progress report: winters 2000 and 2001. Unpubl. report, USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana. 42 pp.
- Squires, J. R., N. J. DeCesare, S. Tomson, L. F. Ruggiero, and B. Oakleaf. 2003. Distribution of lynx and other forest carnivores in the Wyoming Range, southcentral Wyoming. Final Report. USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana, and the Wyoming Game and Fish Department. 46 pp.
- Squires, J. R., L. F. Ruggiero, and J. A. Kolbe. 2004a. Ecology of lynx in western Montana, including Seeley Lake. Progress report - January 2003-September 2004. Unpubl. report, USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana. 21 pp.

- Squires, J. R., K. S. McKelvey, and L. F. Ruggiero. 2004b. A snow-tracking protocol used to delineate local lynx, *Lynx canadensis*, distributions. *Can. Field-Naturalist* 118:583-589.
- Squires, J. R., N. J. DeCesare, J. A. Kolbe, and L. F. Ruggiero. 2004c. Movements of lynx relative to landscape features, including transportation corridors. 2004 progress report. Unpubl. report. USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana. 32 pp.
- Squires, J. R., L. F. Ruggiero, J. A. Kolbe, and N. J. DeCesare. 2006a. Lynx ecology in the intermountain west. Unpubl. report. USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana. 51 pp.
- Squires, J. R., D. H. Pletscher, T. J. Ulizio, and L. F. Ruggiero. 2006b. The association between landscape features and transportation corridors on movements and habitat-use patterns of wolverines. Final report, June 2006. Unpubl. report. USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana. 53 pp.
- Squires, J. R., N. J. DeCesare, J. A. Kolbe, and L. F. Ruggiero. 2008. Hierarchical den selection of Canada lynx in western Montana. *Journal of Wildlife Management* 72:1497-1506.
- Squires, J. R., N. J. DeCesare, J. A. Kolbe, and L. F. Ruggiero. 2010. Seasonal resource selection of Canada lynx in managed forests of the Northern Rocky Mountains. *Journal of Wildlife Management* 74:1648-1660.
- Squires, J. R., L. E. Olson, D. L. Turner, N. J. DeCesare, and J. A. Kolbe. 2012. Estimating detection probability for Canada lynx *Lynx Canadensis* using snow-track surveys in the Northern Rocky Mountains, Montana, USA. *Wildlife Biology* 18:215-224.
- Squires, J. R., N. J. DeCesare, L. E. Olson, J. A. Kolbe, M. Hebblewhite, and S. A. Parks. 2013. Combining resource selection and movement behavior to predict corridors for Canada lynx at their southern range periphery. *Biological Conservation* 157:187-195.
- Squires J., J. Ivan, and R. Ghormley. 2016. Canada Lynx and Snowshoe Hare Response to Spruce-Beetle Tree Mortality, April 2016 Update. Unpublished. 5pp.
- Staples, W. R. 1995. Lynx and coyote diet and habitat relationships during a low hare population on the Kenai peninsula, Alaska. - M. S. Thesis, University of Alaska, Fairbanks, Alaska, USA, 150 pp.
- Starfield, A. M. and F. S. Chapin, III. 1996. Model of transient changes in arctic and boreal vegetation in response to climate and land use change. *Ecol. Applications* 6:842-864.
- State of Minnesota. 2016. 84.0895 Protection of threatened and endangered species.
- Stenseth, N. C., Kung-Sik Chan, H. Tong, R. Boonstra, S. Boutin, C. J. Krebs, E. Post, M. O'Donogue, H. G. Yoccoz, M. C. Forchhammer, and J. W. Hurrell. 1999. Common dynamic structure of Canada lynx populations within three climatic regions. *Science* 285:1071-1073.
- Stenseth, N. C., G. Ottersen, J. W. Hurrell, A. Mysterud, M. Lima, Kung-Sik Chan, H. G. Yoccoz, and B. Adlandsvik. 2003. Studying climate effects on ecology through the use of

- climate indices: the North Atlantic Oscillation, El Nino Southern Oscillation and beyond. The Royal Society of London B 270:2087-2096.
- Stenseth, N. C., A. Shabbar, K. S. Chan, S. Boutin, E. K. Rueness, D. Ehrich, J. W. Hurrell, O. C. Lingjaerde, and K. S. Jakobsen. 2004. Snow conditions may create an invisible barrier for lynx. *Proceedings of the National Academy of Sciences* 101:10632-10634.
- Steury, T. D. and D. L. Murray. 2004. Modeling the reintroduction of lynx to the southern portion of its range. *Biological Conservation* 117:127-141.
- Stinson, D. W. 2001. Washington State recovery plan for the lynx. Washington Department of Fish and Wildlife, Olympia, Washington. 78 pp. + 5 maps.
- Stocks, B. J. 1987. Fire behavior in immature jack pine. *Canadian Journal of Forest Research* 17.1: 80-86.
- Stocks, B. J., M. A. Fosberg, T. J. Lynham, L. Mearns, B. M. Wotton, Q. Yang, J-Z Jin, K. Lawrence, G. R. Hartley, J. A. Mason, and D. W. McKenney. 1998. Climate change and forest fire potential in Russian and Canadian boreal forests. *Climatic Change* 38:1-13.
- Stoelinga, M.T., M.D. Albright, and C.F. Mass. 2010. A new look at snowpack trends in the Cascade Mountains. *American Meteorological Society*. 23:2473-2491.
- Strohm, S. and R. Tyson 2009. The effect of habitat fragmentation on cyclic population dynamics: a numerical study. *Bulletin of Mathematical Biology* 71.6:1323-1348.
- Sturm, M. S., J. P. McFadden, G. E. Liston, F. S. Chapin III, C. H. Racine, and J. Holmgren. 2001. Snow-shrub interactions in the arctic tundra: a hypothesis with climatic implications. *Journal of Climate* 14:336-344.
- Sturtevant, B. R., B. R. Miranda, D. J. Shinneman, E.J. Gustafson, and P. T. Wolter. 2012. Comparing modern and presettlement forest dynamics of a subboreal wilderness: Does spruce budworm enhance fire risk? *Ecological Applications* 22:1278-1296.
- Sullivan, T. P. 1996. Influence of forest herbicide on snowshoe hare population dynamics; reproduction, growth, and survival. *Canadian Journal of Forest Research* 26:112-119.
- Sullivan, T. P. and D. S. Sullivan. 1988. Influence of stand thinning on snowshoe hare population dynamics and feeding damage in lodgepole pine forest. *Journal of Applied Ecology* 25:791-805.
- Sultaire, S. M., J. N. Pauli, K. J. Martin, M. W. Meyer, M. Notaro, and B. Zuckerberg. 2016a. Climate change surpasses land-use change in contracting range boundary of a winter-adapted mammal. *Proceedings of the Royal society B* 283:20153104.
- Sultaire, S. M., J. N. Pauli, K. J. Martin, M. W. Meyer, B. Zuckerberg. 2016b. Extensive forests and persistent snow cover promote snowshoe hare occupancy in Wisconsin. *The Journal of Wildlife Management* 80:894-905.
- Sustainable Forestry Initiative. 2015. SFI 2015-2019 Standards and rules. <http://www.sfiprogram.org/files/pdf/2015-2019-standardsandrules-web-lr-pdf/>

- Swanson C. S. and J. B. Loomis. 1996. Role of nonmarket economic values in benefit-cost analysis of public forest management. Portland (OR): USDA Forest Service. General Technical Report PNW-GTR-361.
- Tang, G. and B. Beckage. 2010. Projecting the distribution of forests in New England in response to climate change. *Diversity and Distributions* 16:144-158.
- Tebaldi, C., D. Adams-Smith, and A. Kenward. 2013. Warming winters: U. S. temperature trends. Climate Central. <http://www.climatecentral.org/wgts/warming-winters/WarmingWinters.pdf>.
- Tennant, C. J., B. T. Crosby, S. E. Godsey, R. W. VanKirk, and D. R. Derryberry. 2015. A simple framework for assessing the sensitivity of mountain watersheds to warming-driven snowpack loss. *Geophysical Research Letters* 42:2814-2822.
- Thiel, R. P. 1987. The status of Canada lynx in Wisconsin, 1865-1980. *Wisconsin Academy of Sciences, Arts and Letters*. pp. 90-96.
- Thomas, J. A., J. G. Hallett, and M. A. O'Connell. 1997. Habitat use by snowshoe hares in managed landscapes of northeastern Washington. Report submitted to Washington Department of Fish and Wildlife, USDA Forest Service.
- Thompson, I. D., J. A. Baker, and M. Ter-Mikaelian. 2003. A review of the long-term effects of post-harvest silviculture on vertebrate wildlife, and predictive models, with an emphasis on boreal forests in Ontario, Canada. *Forest Ecology and Management* 177:441-469.
- Thompson, R. W. and J. C. Halfpenny. 1989. Canada lynx presence on the Vail ski area and proposed expansion areas. Unpubl. Rep., Western Ecosystems, Inc., Lafayette, CO.
- Thompson, R. W. and J. C. Halfpenny. 1991. Canada lynx presence on the proposed East Fork ski area. Unpubl. Rep., Western Ecosystems, Inc., Boulder, CO. 35 pp.
- TNC. 2016a. Clearwater Blackfoot Project: Erasing the great western checkerboard. The Nature Conservancy. 3 pp.
- TNC. 2016b. The Montana legacy project: Frequently asked questions. The Nature Conservancy. 3 pp.
- TNC. 2016c. The Montana Legacy Project – a new era for conservation. The Nature Conservancy in Montana. 6 pp.
- Trani, M. K., R. T. Brooks, T. L. Schmidt, V. A. Rudis, and C. M. Gabbard. 2001. Patterns and trends of early successional forests in the eastern United States. *Wildlife Society Bulletin* 28:413-424.
- Trenberth, K. E., A. Dai, G. van der Schrieer, P. D. Jones, J. Barichivich, K. R. Briffa, and J. Sheffield. 2014. Global warming and changes in drought. *Nat. Climate Change* 4:17-22.
- USDA and USDI. 2003. Interagency strategy for the implementation of Federal wildland fire management policy (June 20, 2003). U.S. Department of Agriculture and U.S. Department of Interior. 57 pp.

- USDA and USDI. 2009. Guidance for implementation of Federal Wildland Fire Management Policy (February, 2009). U.S. Department of Agriculture and U.S. Department of Interior.
- USDI, USDA, DOE, DOD, DOC, USEPA, FEMA, and NASF. 2001. Review and update of the 1995 Federal wildland fire management policy. iv + 78 pp.
- U.S. District Court, Montana. 2014a. Order, CV 13-57-M-DWM, Friends of the Wild Swan, *et al.* vs. Daniel Ashe, *et al.* May 8, 2014. 9 pp.
- U.S. District Court, Montana. 2014b. Order, CV 13-57-M-DWM, Friends of the Wild Swan, *et al.* vs. Daniel Ashe, *et al.* June 25, 2014. 2 pp.
- U.S. District Court, Montana. 2016. Order, CV 14-270-M-DLC (Consolidated with Case No. 14-272-M-DLC), WildEarth Guardians *et al.* vs. U.S. Dept. of the Interior *et al.* September 7, 2016. 30 pp.
- USEPA. 2015. Climate change indicators in the United States: Snowpack. Updated June 2015. www.epa.gov/climatechange/indicators. 3 pp.
- USFS. 2004a. Land and Resource Management Plan, Superior National Forest. USDA Forest Service, Eastern Region, Milwaukee, Wisconsin. July 2004. https://www.fs.usda.gov/detail/superior/landmanagement/planning/?cid=fsm91_049716
- USFS. 2004b. Land and Resource Management Plan, Chippewa National Forest. USDA Forest Service, Eastern Region, Milwaukee, Wisconsin. July 2004. https://www.fs.usda.gov/detail/chippewa/landmanagement/planning/?cid=fsm9_016569
- USFS. 2004c. 2004 Land and Resource Management Plan, Chequamegon-Nicolet National Forests. April 2004. <https://www.fs.usda.gov/detail/cnfn/landmanagement/planning/?cid=stelprdb5117262>
- USFS. 2007. Northern Rockies Lynx Management Direction Record of Decision. USDA Forest Service, National Forests in Montana, and parts of Idaho, Wyoming and Utah. March 2007. 71 pp.
- USFS. 2008a. Southern Rockies Lynx Amendment Record of Decision. USDA Forest Service, Rocky Mountain Region. October 2008. 78 pp.
- USFS. 2008b. Biological Assessment of the Southern Rockies Lynx Amendment on Threatened, Endangered and Proposed Species. U.S. Forest Service Rocky Mountain Region. 132 pp.
- USFS. 2009. Preliminary assessment of environmental attributes necessary to support a viable lynx population on National Forest System lands in northern New Mexico. USDA Forest Service, Southwestern Region, Albuquerque, New Mexico. 30 pp.
- USFS. 2011a. Programmatic Biological Assessment for Federally Listed Species. Superior National Forest. Duluth, Minnesota. 171 pp.

- USFS. 2011b. USDA Forest Service. Western bark beetle strategy: Human safety, recovery and resiliency. Unpublished Report. 24 pp.
http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5337222.pdf
- USFS. 2015a. USDA Forest Service, Region 1. Canada lynx 5-year status review: Lynx documentation 2000 to 2014. March 2015. 40 pp.
- USFS. 2015b. USDA Forest Service. Aerial Survey Highlights for Colorado for 2014. Unpublished Report. 8 pp.
- USFS and BLM. 1999. Biological Assessment of the Effects of National Forest Land and Resource Management Plans and Bureau of Land Management Land Use Plans on Canada Lynx. 165 pp.
- USFS and Colorado State Forest Service. 2014. Aerial survey highlights for Colorado 2014 (insect damage). 8 pp.
- USFS and USFWS. 2000. Canada Lynx Conservation Agreement. Missoula, Montana. 12 pp.
- USFS and USFWS. 2006. Canada Lynx Conservation Agreement. Missoula, Montana. 17 pp.
- USFWS. 2000. Biological opinion on the effects of National Forest Land and Resource Management Plans and Bureau of Land Management Land Use Plans on Canada lynx (*Lynx canadensis*) in the contiguous United States. USDI Fish and Wildlife Service, Denver, Colorado. October 25, 2000. 82 pp.
- USFWS. 2001. Biological opinion on the effects of the CITES Export Program for Appendix-II furbearer species on the contiguous United States Distinct Population Segment of the Canada lynx. USDI Fish and Wildlife Service, Washington, D.C. September 24, 2001. 21 pp.
- USFWS. 2005. Draft recovery outline for the contiguous United States distinct population segment of the Canada lynx. Unpublished draft. USDI Fish and Wildlife Service, Region 6, Denver, Colorado. 21 pp.
- USFWS. 2007. Biological opinion on the effects of the Northern Rocky Mountains Lynx Amendment on the Distinct Population Segment (DPS) of Canada lynx (*Lynx canadensis*) (lynx) in the contiguous United States. USDI Fish and Wildlife Service, Helena, Montana. March 23, 2007. 125 pp.
- USFWS. 2008a. Revised critical habitat for the contiguous United States distinct population segment of the Canada lynx relative to the Kettle Range in Washington State. Memorandum, Region 1 to Region 6. USDI Fish and Wildlife Service, Spokane, Washington. June 5, 2008. 7 pp.
- USFWS. 2008b. Biological opinion on the effects of the Southern Rockies Lynx Amendment (SRLA) on the Distinct Population Segment (DPS) of Canada lynx (*Lynx canadensis*) (lynx) in the contiguous United States. USDI Fish and Wildlife Service, Denver, Colorado. July 25, 2008. 93 pp.

- USFWS. 2011a. Eastern puma (=cougar) (*Puma concolor couguar*) 5-YEAR REVIEW: Summary and Evaluation. USDI Fish and Wildlife Service, Orono, Maine. March, 2011. 107 pp.
- USFWS. 2011b. Biological opinion on the revised Land and Resource Management Plan (Forest Plan) for the Superior National Forest and its effects on the gray wolf (*Canis lupus*), gray wolf critical habitat, Canada lynx (*Lynx canadensis*), and Canada lynx critical habitat. USDI Fish and Wildlife Service, Bloomington, Minnesota. September 16, 2011. 82 pp.
- USFWS. 2014. Incremental Effects Memorandum for the Economic Analysis for the Proposed Rule to Revise the Designation of Critical Habitat for the Contiguous United States Distinct Population Segment of the Canada Lynx. 50 pp.
- USFWS. 2015a. News release: Service conducting five-year review for Canada lynx in preparation of recovery Planning. https://www.fws.gov/mountain-prairie/pressrel/2015/01132015_ServiceConductingFiveYearReviewCanadaLynx.php
- USFWS. 2016a. USFWS Species Status Assessment Framework. Version 3.4. August 2016. 21 pp. https://www.fws.gov/endangered/improving_ESA/pdf/SSA_Fact_Sheet-August_2016.pdf
- USFWS_2016b. Canada lynx incidental take database, Minnesota. Unpubl. data. USDI Fish and Wildlife Service, Bloomington, Minnesota.
- USFWS. 2016c. Lynx vehicle mortalities update, February 24, 2016. *Unpubl. data*. Compiled by K. Broderdorp, USDI Fish and Wildlife Service, Grand Junction, Colorado. 7 pp.
- United States National Assessment Team (2000) Climate change impacts on the United States: The potential consequences of climate variability and change. US Global Change Research Program. Cambridge University Press, New York, USA
- University of Alaska Center for Conservation Science. 2016. Canadian lynx annual distribution. 1 pp. <http://akgap.uaa.alaska.edu/species-data/canadian-lynx-annual-distribution/>, Accessed 4/28/2016.
- University of Minnesota. 2013. Mean annual snowfall statistics for Minnesota. http://www.climate.umn.edu/snow_fence/Components/SFF/MeanSF/aveannual1971-2000.htm. Accessed May 15, 2013.
- Vail, D. 2007. Tourism strategy for the Maine Woods: A big push to world class. Maine Policy Review 16.2: 104-115. <http://digitalcommons.library.umaine.edu/cgi/viewcontent.cgi?article=1167&context=mpr>.
- Vanbianchi, C.M. 2015. Habitat use and connectivity for Canada lynx in the North Cascade Mountains, Washington. M.S. Thesis, University of British Columbia (Okanagan). 271 pp..
- van Mantgem, P.J., Stephenson, N.L., Byrne, J.C., Daniels, L.D., Franklin, J.F., Fule, P.Z., Harmon, M.E., Larson, A.J., Smith, J.M., Taylor, A.H., Veblen, T.T., 2009. Widespread increase of tree mortality rates in the western United States. Science 323:521–524.

- van Oort, H., B. McLellan, and R. Serrouya. 2011. Fragmentation, dispersal and metapopulation function in remnant populations of endangered mountain caribou. *Animal Conservancy*. 14:215-224.
- van Zyll de Jong, C. G. 1966. Parasites of the Canada lynx *Felis (Lynx) canadensis* (Kerr). *Canadian Journal of Zoology* 44:499-509.
- van Zyll de Jong, C. G. 1971. The status and management of the Canada lynx in Canada. Pp. 16-19 in Jorgensen, S. E. and L. D. Mech (eds.). *Proceedings of a symposium on the native cats of North America: Their status and management*. U.S. Dept. of Interior Fish and Wildlife Service, Twin Cities, MN, September 1971.
- Vashon, J. Maine Department of Inland Fisheries and Wildlife, Unpublished data.
- Vashon, J. 2017. Personal communication re: Lynx Maine Update; electronic mail to J. Zelenak, USFWS, Helena, MT, October 11, 2017.
- Vashon, J. 2015. *Lynx canadensis*. *The IUCN Red List of Threatened Species 2015*: e.T12518A50655041. <http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T12518A50655041.en>
- Vashon, J. H., A. L. Meehan, W. J. Jakubas, J. F. Organ, A. D. Vashon, C. R. McLaughlin, and G. J. Matula, Jr. 2005a. Preliminary diurnal home range and habitat use by Canada lynx (*Lynx canadensis*) in northern Maine. Unpubl. report, Maine Department of Inland Fisheries and Wildlife, Bangor, Maine. 29 pp.
- Vashon, J. H., J. F. Organ, W. J. Jakubas, A. D. Vashon, G. J. Matula Jr., C. R. McLaughlin, and S. M. Crowley. 2005b. Reproduction and mortality of Canada lynx (*Lynx canadensis*) in northern Maine. Unpubl. report, Maine Department of Inland Fisheries and Wildlife, Bangor, Maine. 15 pp.
- Vashon, J. H., A. L. Meehan, W. J. Jakubas, J. F. Organ, A. D. Vashon, C. R. McLaughlin, G. J. Matula, Jr., and S. M. Crowley. 2008a. Spatial ecology of a Canada lynx population in northern Maine. *Journal of Wildlife Management* 72:1479–1487.
- Vashon, J. H., A. L. Meehan, J. F. Organ, W. J. Jakubas, C. R. McLaughlin, A. D. Vashon, and S. M. Crowley. 2008b. Diurnal habitat relationships of Canada lynx in an intensively managed private forest landscape in northern Maine. *Journal of Wildlife Management* 72:1488–1496.
- Vashon, J., S. McLellan, S. Crowley, A. Meehan, and K. Laustsen. 2012. Canada lynx assessment. Maine Dept. Inland Fisheries and Wildlife, Research and Assessment Section, Bangor, Maine. 107 pp.
- Vaughan, D.G., J.C. Comiso, I. Allison, J. Carrasco, G. Kaser, R. Kwok, P. Mote, T. Murray, F. Paul, J. Ren, E. Rignot, O. Solomina, K. Steffen and T. Zhang, 2013: Observations: Cryosphere. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

- Veblen, T. T., K. S. Hadley, E. M. Nel, T. Kitzenberger, M. Reid, and R. Villalba. 1994. Disturbance regime and disturbance interactions in a Rocky Mountain subalpine forest. *Journal of Ecology* 82:125-135.
- Vermont Wildlife Action Plan Team. 2015. Vermont Wildlife Action Plan 2015. Vermont Fish & Wildlife Department. Montpelier, VT. <http://www.vtfishandwildlife.com>.
- Volney, W. J. A. and R. A. Fleming. 2000. Climate change and impacts of boreal forest insects. *Agricultural Ecosystems and Environment* 82:283-294.
- von Kienast, J. A. 2003. Winter habitat selection and food habits of lynx on the Okanogan Plateau, Washington. M.S. Thesis, University of Washington, Seattle. 57 pp.
- Wade, A. A., A. P. Ballantyne, A. J. Larson, and W. M. Jolly. 2017. Forests and climate change in Montana. Ch 4 in Whitlock, C., Cross, W., Maxwell, B., Silverman, N., and Wade, A. A. 2017. *2017 Montana Climate Assessment*. Bozeman and Missoula MT: Montana State University and University of Montana, Montana Institute on Ecosystems. 318 p. doi:10.15788/m2ww8w. <http://montanacclimate.org/chapter/forests>.
- WADFW. 2016. DNS 16-038: Uplisting lynx from a state threatened species to a state endangered species. Washington Department of Fish and Wildlife, Olympia, Washington. 2pp.
- WADNR. 2006. Lynx habitat management plan for DNR-managed lands. State of Washington Department of Natural Resources, Olympia, Washington. 166 pp. http://www.dnr.wa.gov/Publications/lm_ess_lynx_plan_final.pdf.
- WAFWC. 2016. Minutes, Washington Fish and Wildlife Commission Meeting, December 9-10, 2016. 5 pp.
- Wagner, S., S. Nocentini, F. Huth, and M. Hoogstra-Klein. 2014. Forest management approaches for coping with the uncertainty of climate change: trade-offs in service provisioning and adaptability. *Ecology and Society* 19(1):32.
- Wagner, R.G., J. Bryant, B. Burgason, M. Doty, B.E. Roth, P. Strauch, D. Struble, and D. Denico. 2015. Coming Spruce Budworm Outbreak: Initial Risk Assessment and Preparation & Response Recommendations for Maine's Forestry Community. Cooperative Forestry Research Unit, University of Maine, Orono. 77p. http://www.sprucebudwormmaine.org/docs/SBW_full_report_web.pdf.
- Wake, C. 2005. Indicators of Climate Change in the Northeast over the Past 100 Years.
- Walker, C. J. 2005. Influences of landscape structure on snowshoe hare populations in fragmented forests. M.S. Thesis, University of Montana, Missoula. 95 pp.
- Walpole, A. A., J. Bowman, D. L. Murray, and P. J. Wilson. 2012. Functional connectivity of lynx at the southern range periphery in Ontario, Canada. *Landscape Ecology* 27:761-773.
- Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, S. Doney, R. Feely, P. Hennon, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville. 2014. Ch. 2: Our Changing

Climate. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 19-67. doi:10.7930/J0KW5CXT.
<http://nca2014.globalchange.gov/report/our-changing-climate/introduction>.

- Ward, R. M. P. and C. J. Krebs. 1985. Behavioral responses of lynx to declining snowshoe hare abundance. *Canadian Journal of Zoology* 63:2817-2824.
- WADFW. 2017. Washington Department of Fish and Wildlife Comments: Species status assessment for the Canada lynx (*Lynx canadensis*) contiguous United States distinct population segment, Version 1.0 – Draft – December 2016.
- Watry, M.K. 2016. Personal communication; email to Kurt Broderdorp, USFWS, Grand Junction, CO.
- Weber, M. G. and M. D. Flannigan. 1997. Canadian boreal forest ecosystem structure and function in a changing climate: impact on fire regimes. *Environmental Review* 5:145-166.
- Werdelin, L. 1981. The evolution of lynxes. *Annales Zoologici Fenneci* 18(1):37-71.
- Westerling, A. L. 2016. Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring. *Phil. Trans. R. Soc. B* 371:20150178.
<http://dx.doi.org/10.1098/rstb.2015.0178>.
- Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. *Science*. 313:940-943.
- Whitman, A., A. Cutko, P. deMaynadier, S. Walker, B. Vickery, S. Stockwell, and R. Houston. 2013. *Climate Change and Biodiversity in Maine: Vulnerability of Habitats and Priority Species*. Manomet Center for Conservation Sciences (in collaboration with Maine Beginning with Habitat Climate Change Working Group) Report SEI-2013-03. 96 pp. Brunswick, Maine.
- Wild, M. A., T. M. Shenk, and R. R. Spraker. 2006. Plague as a mortality factor in Canada lynx (*Lynx canadensis*) reintroduced to Colorado. *Journal of Wildlife diseases* 42:646-650.
- Williams, D. W. and A. M. Liebhold 1997. Latitudinal shifts in spruce budworm (Lepidoptera: Tortricidae) outbreaks and spruce-fir forest distributions with climate change. *Acta Phytopathologica et Entomologica Hungarica* 32:205-215.
- Wirsing, A. J., T. D. Steury, and D. L. Murray. 2002. A demographic analysis of a southern snowshoe hare population in a fragmented habitat: evaluating the refugium model. *Canadian Journal of Zoology* 80:169-177.
- Wrigley, M. 2016. Personal communication; email to Kurt Broderdorp, USFWS, Grand Junction, CO.
- Wolfe, M. L., N. V. Debyle, C. S. Winchell, and T. R. McCabe. 1982. Snowshoe hare cover relationships in northern Utah. *Journal of Wildlife Management* 49:662-670.

- Wolff, J. O. 1980. The role of habitat patchiness in the population dynamics of snowshoe hares. *Ecological Monographs* 50:111-130.
- Wolff, J. O. 1981. Refugia, dispersal, predation, and geographical baritation in snowshoe hare cycles. In: Meyers K, MacInnes CD (eds) *Proceedings of the world largomorph conference*. University of Guelph, Guelph, pp. 441-448.
- Woodall, C. W., P. J. Ince, K. E. Skog, F. X. Aguilar, C. E. Keegan, C. B. Sorenson, D. G. Hodges, and W. B. Smith. 2011. An overview of the forest products sector downturn in the United States. *Forest Product Journal* 61:595-603.
- Yan, C., N. C. Stenseth, C. J. Krebs, and Z. Zhang. 2013. Linking climate change to population cycles of hares and lynx. *Global Change Biology* 19:3263-3271.
- Zahratka, J. L. and T. M. Shenk. 2008. Population estimates of snowshoe hares in the Southern Rocky Mountains. *Journal of Wildlife Management* 72:906-912.
- Zhu Z, C. E. Woodcock, and P. Olofsson. 2012. Continuous monitoring of forest disturbance using all available Landsat imagery. *Remote Sensing of Environment* 122:75-91.
- Zimmerman, G. T. and D. L. Bunnell. 2000. The Federal wildland fire policy: Opportunities for wilderness fire management. Pp. 288-297 *in* USDA Forest Service Proceedings, RMRS-P-15-VOL-5.
- Zimova, M. 2013. Camouflage mismatch in seasonal coat color due to decreased snow duration: will snowshoe hares keep up with climate change? M. S. thesis. University of Montana, Missoula, Montana. 105pp.
- Zimova, M., L. S. Mills, P. M. Lukacs, and M. S. Mitchell. 2014. Snowshoe hares display limited phenotypic plasticity to mismatch in seasonal camouflage. *Proceedings of the Royal Society B* 281:20140029.
- Zimova, M., L. S. Mills, and J. Joshua Nowak. 2016. High fitness costs of climate change-induced camouflage mismatch. *Ecology Letters* 19:299-307.