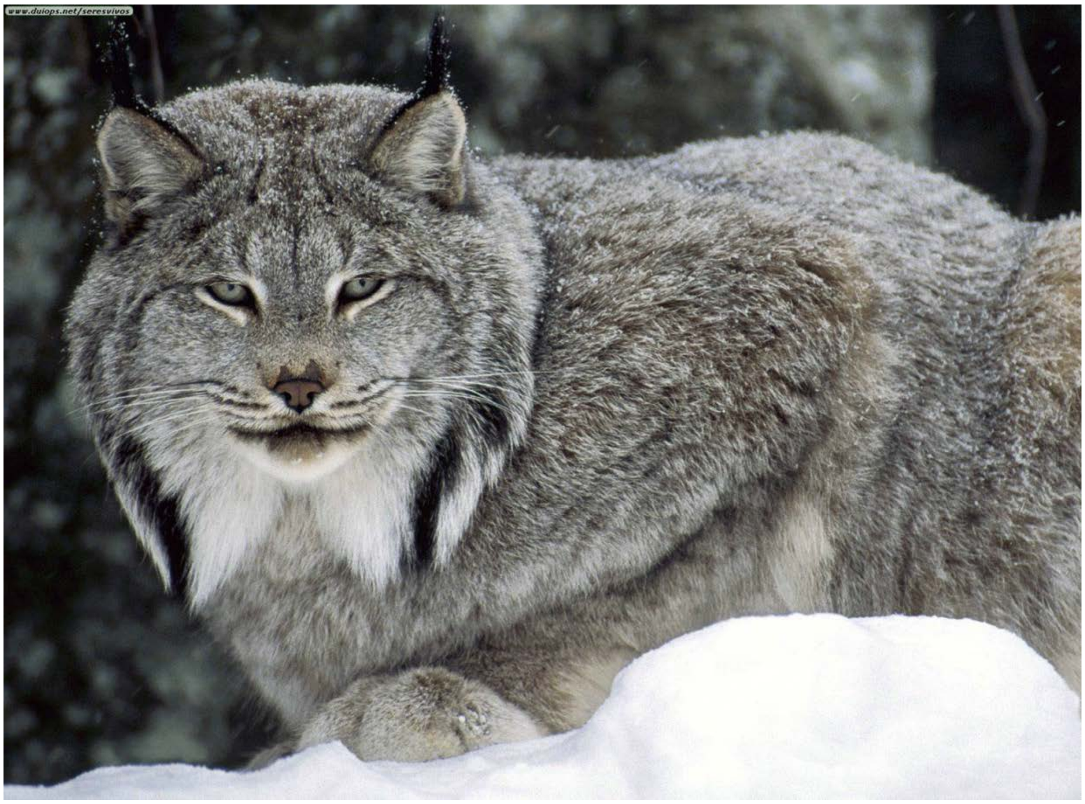
Canada Lynx Expert Elicitation Workshop

October 13-15, 2015 - Bloomington, Minnesota



Final Report

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Executive Summary

As part of a species status assessment (SSA) for the contiguous United States distinct population segment (DPS) of the Canada lynx, the U.S. Fish and Wildlife Service (Service) convened an expert elicitation workshop to gather (1) the best available information on the current status of lynx populations within the DPS and (2) the professional judgment and opinions of lynx experts regarding the future viability of the DPS. This report summarizes the results of the workshop regarding the current and likely future condition of lynx populations in six geographic areas within the DPS in terms of representation, redundancy, and resiliency. The Service will incorporate the information gathered at this workshop into the SSA as appropriate, along with the published scientific literature, to inform recovery planning for the DPS and any other determinations the Service is authorized and required to make in accordance with the Endangered Species Act.

Purpose

The purpose of this report is to convey the results of an expert workshop convened by the U.S. Fish and Wildlife Service (Service) in October 2015 to improve our understanding of the status of the contiguous U.S. distinct population segment (DPS) of Canada lynx (*Lynx canadensis*). This workshop was held in conjunction with a species status assessment (SSA; see Appendix 1 [All appendices are accessible at: http://www.fws.gov/mountain-prairie/es/canadaLynx.php]) for the DPS. The SSA, which will incorporate the best available scientific information on lynx, is needed to inform the Service's response to a June 2014 court order to complete a recovery plan for the DPS by January 2018, or make a formal determination that a recovery plan is not necessary.

The workshop was organized by a Lynx SSA Team consisting of Service and USGS staff who have developed and piloted implementation of the SSA framework, and Service biologists who are working on lynx throughout the range of the DPS. In the interest of collaboration and transparency, this team partnered with State agencies, other Federal agencies, and academic researchers to elicit expert input regarding the current and likely future status of lynx populations within the DPS.

Expert input is needed to complement the published scientific literature and other available information on many aspects of lynx population dynamics in the DPS range. In particular, we were looking for additional information on the status, sizes, and trends of lynx populations and on threats to lynx habitats and those of their primary prey, snowshoe hares (*Lepus americanus*). We therefore designed a process to elicit and capture the knowledge, professional judgments, and opinions of lynx experts to help us assess the current status of, and the nature and magnitude of potential threats to, lynx populations and habitats within the DPS. We also sought expert knowledge to help us evaluate the viability of the DPS (in terms of the "3 Rs" - redundancy, representation, and resiliency; see definitions below) under a range of future threats, habitat conditions, and climate scenarios, and to identify and make explicit areas of uncertainty and potential differences of opinion among experts.

The results of the workshop will contribute to the SSA, which will compile and summarize the best available scientific and commercial data, including empirical data, published literature, and expert input. This information will then be used by Service decision makers to inform recovery planning direction, classification decisions, and other determinations required by the Endangered Species Act (ESA).

Background

The Canada lynx is a medium-sized cat with long legs and large, well-furred paws. Its long, black ear tufts and short, black-tipped tail distinguish the lynx from the similar bobcat (*Lynx rufus*), which is much more common in the contiguous U.S. The lynx's large feet and long legs make it highly adapted for hunting snowshoe hares in the deep or powdery snow that persists across much of its boreal forest distribution, most of which occurs in Canada and Alaska. These adaptations provide lynx a competitive advantage over potential competitors, such as bobcats or coyotes (*Canis latrans*), which have much smaller feet and higher foot-loadings that prevent them from hunting efficiently in deep, powdery snow (McCord and Cardoza 1982, p. 748; Buskirk *et al*. 2000, pp. 86–95; Ruediger *et al*. 2000, pp. 1–11; Ruggiero *et al*. 2000, pp. 445, 450).

The southern periphery of the boreal forest extends into parts of the northern contiguous U.S., where it transitions to the Acadian forest in the Northeast (Seymour and Hunter 1992, pp. 1, 3), deciduous temperate forest in the Great Lakes regions, and subalpine forest in the Rocky Mountains and Cascade Mountains in the west (Agee 2000, pp. 40–41). In the contiguous U.S., these transitional boreal forests become discontinuous and patchy, preventing both lynx and hares from broadly achieving densities similar to those of the northern boreal forests (Wolff 1980, pp. 123–128; Buehler and Keith 1982, pp. 24, 28; Koehler 1990, p. 849; Koehler and Aubry 1994, p. 84; Aubry *et al*. 2000, pp. 373–375, 382, 394). These forests eventually become too fragmented and isolated in the contiguous United States to support hares at the landscape densities and distributions necessary to support lynx home ranges (Interagency Lynx Biology Team 2013, p. 77) or lynx populations over time.

The Service designated lynx in the contiguous U.S. 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 and lynx habitats occurred on national forests, and that the Land and Resource Management Plans that guided management of those forests 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). 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 (U.S. Fish and Wildlife Service 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 U.S. constitute a single DPS (72 FR 1186). Also in 2007, the Service initiated 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 extend ESA protection to lynx "where found" in the contiguous U.S., including New Mexico and other states that were not included in the original DPS range (79 FR 54804).

Although the Service originally identified the DPS as occurring in forested portions of 14 states (Colorado, Idaho, Maine, Michigan, Minnesota, Montana, New Hampshire, New York, Oregon, Utah, Vermont, Washington, Wisconsin, and Wyoming) (65 FR 16052, 16085), it recognized at the time of listing that both lynx and the boreal forests that support them in the Lower 48 States are at the southern margins of their ranges, where habitats naturally become patchy and fragmented and snowshoe hare densities in many places are not consistently high enough to support resident lynx populations (65 FR 16052-59). It also recognized that inherent limitations in historic occurrence information made it difficult to distinguish between areas that consistently supported resident populations; other areas that may have occasionally supported resident, breeding lynx; and yet other areas that intermittently and temporarily contained dispersing or transient lynx but did not support lynx home ranges or reproduction (65 FR 16054-59). Many lynx records in the DPS range seem to have been associated with cyclic "irruptions" of lynx from southern Canada into the northern contiguous U.S. when northern hare populations crashed, as they did historically every 8-11 years (Elton and Nicholson 1942, entire; McKelvey *et al*. 2000, entire; Mowat *et al*. 2000, pp. 281–294; Interagency Lynx Biology Team 2013, p. 33). Lack of reliable information also precluded determination of sizes or trends of lynx populations within the DPS.

Recent research and monitoring have improved our understanding of many aspects of lynx biology, distribution, and potential threats in the DPS. However, we still lack reliable estimates of the sizes and important demographic rates of most populations. Likewise, we would benefit from further understanding of the natural range and causes of variation in lynx and hare numbers; hare densities necessary to support resident lynx populations throughout the DPS; the influence of immigration of lynx from Canada on the demographic and genetic fitness of DPS populations; and the timing, extent, magnitude, and severity of potential threats associated with climate change. The Lynx SSA Team organized this expert elicitation workshop to help fill some of these information gaps with the knowledge, professional judgments, and opinions of lynx experts.

Currently, there are five geographic areas known to support resident lynx populations in the DPS: northern Maine (with occasional/sporadic breeding by small numbers of lynx in northernmost New Hampshire and Vermont); northeastern Minnesota; northwestern Montana and northeastern Idaho; north-central Washington; and western Colorado (Figure 1). After statewide surveys conducted in 1978-1997 suggested the absence of viable resident lynx populations in Colorado, the State, from 1999 to 2006, released 218 lynx captured in Canada and Alaska into southwest Colorado to establish the current resident population. Additionally, the Greater Yellowstone Area (GYA) of southwestern Montana and northwestern Wyoming is believed historically (and as recently as 2003-04) to have supported a small but relatively persistent lynx population, but it is uncertain whether it currently supports any resident lynx.

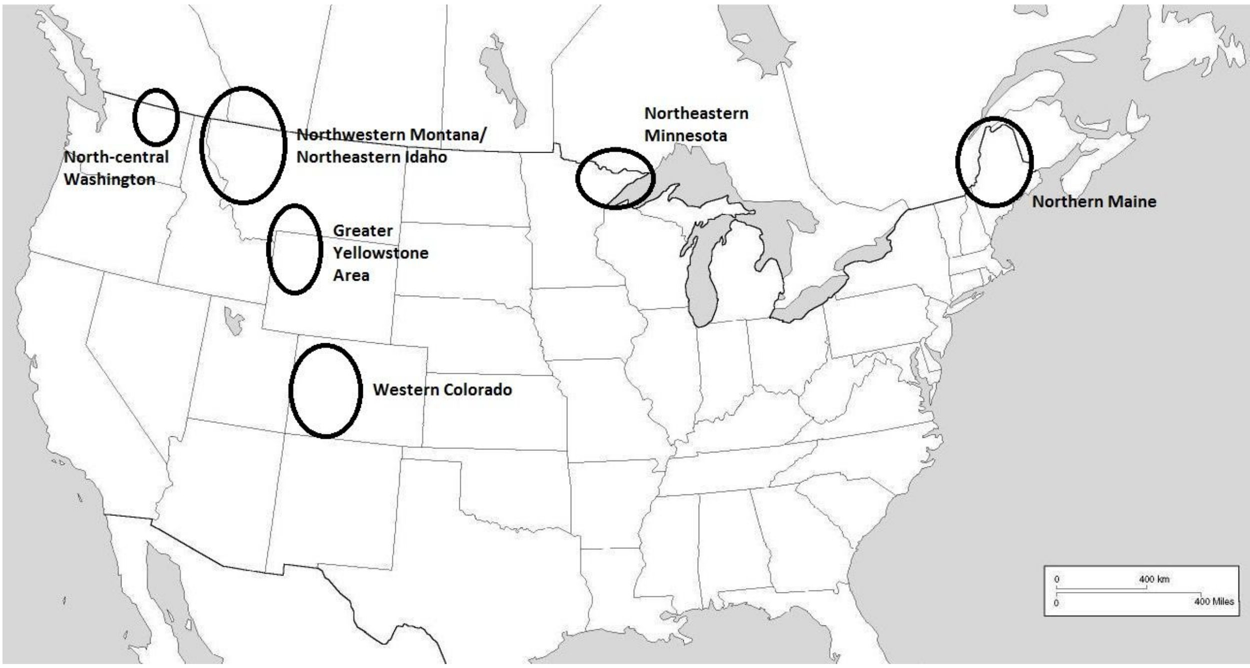

Figure 1. Six geographic units within the range of the contiguous U.S. distinct population segment of Canada lynx (*Lynx canadensis*) that currently support or recently supported (GYA) resident lynx populations.

Expert Elicitation

Workshop Protocol

As mentioned under *Purpose*, above, the Lynx SSA Team convened the October 2015 workshop to elicit expert knowledge and opinion on critical uncertainties regarding the current status and future viability of resident lynx populations within the DPS range, and thus the DPS as a whole. To facilitate this, a 10-member panel of recognized lynx experts from across the DPS range first observed and discussed presentations by subject matter experts summarizing the current state of available information on topics relevant to lynx populations in the DPS (see *Preparing Experts* section below). After subject matter presentations, members of the lynx expert panel presented updates on lynx populations in each of the six geographic areas described above under *Background*. The subject matter and update presentations were intended to ensure that all lynx experts had a common baseline of information prior to the elicitation process.

In accordance with the expert elicitation literature (e.g., Burgman 2005, USEPA 2011, Gregory *et al*. 2012, Drescher *et al*. 2013, Morgan 2014), we then used best practices to elicit opinions from the expert panel. Although invited experts were expected to contribute openly and effectively to group discussions, we did not seek consensus among experts; rather, we probed differences of opinion or interpretation of scientific and technical information. We also asked experts and other participants to focus on scientific questions and to refrain from discussing or recommending management or policy decisions related to the Service's authorities and responsibilities in implementing the ESA.

In addition to the lynx expert panel and subject matter experts, workshop participants included members of the USFWS/USGS Lynx SSA Team, facilitators, and observers (see Appendix 2 for a full list of attendees and their respective roles). As a basic ground rule, only members of the expert panel participated in the elicitation process, although panelists were encouraged to confer with the subject matter specialists and SSA Team members as needed. All workshop participants were welcome to participate in discussions that ensued from review of panel responses to various questions. Due to time constraints and to minimize interference with the elicitation process, observers were encouraged to write and submit "parking lot" questions, which were collected at the end of the first two days of the workshop and presented to lynx and subject matter experts for responses and discussion the following mornings (see workshop notes, Appendix 3). The expert elicitation process was facilitated by USFWS and USGS structured decision making practitioners who encouraged open discussion among experts, structured input from both panelists and subject matter experts, and ensured that observers could witness the process without inappropriately influencing it.

Identifying Experts

SSA Team members reviewed the relevant literature and used their first-hand knowledge to identify experts involved in lynx and hare research or management, boreal forest ecology, and climate modeling. We then developed *a priori* selection criteria based on professional credentials, positions, areas of expertise, and pertinent experience to develop a list of candidate lynx experts and other subject matter experts. Selection criteria (below) helped ensure that invitations to participate were made only to scientists with expertise highly relevant to workshop topics and, further, that the selections were transparent, unbiased, and adequately captured the diversity of expertise and professional judgments related to the topics. Selection was not based on affiliation with a particular organization or interested party; however, States and other partners were asked to review the draft list of workshop invitees and suggest alternate or additional qualified experts. The SSA Team then invited experts who met the selection criteria and represented lynx expertise throughout the range of the DPS and in adjacent southern

Canada. The number of invited experts was necessarily limited to improve the efficiency and effectiveness of the elicitation process, avoid redundancy, maximize scientific discussion among all participants, and maintain an open, comfortable meeting environment.

Expert Selection Criteria

Expert panelist candidates had to meet <u>all</u> of the following criteria:

1. Candidate must hold a graduate degree in a scientific discipline highly relevant to the workshop topics. Typically this may include advanced degrees in wildlife biology, ecology, zoology, genetics, modeling, or statistical inference.

2. Candidate must hold a research position in government (State, Tribal, or Federal), academia, or in the nonprofit research sector; or participant must hold a governmental management agency position with responsibility for the species' conservation.

3. Candidate must have expertise in the ecology or management of the species or related species, demonstrated by recent (within the past 10 years) peer-reviewed publications or related types of professional scientific expression.

Candidates also had to meet <u>one or more</u> of the following criteria:

4. Candidate is directly engaged in the species' management, monitoring, or analysis of populations or habitat.

5. Candidate is directly engaged in the study of a specific workshop topic.

6. Candidate is a government or academic research scientist with expertise in conservation biology, population or landscape ecology, genetics, or other relevant fields, as demonstrated by recent (within the past 10 years) peer-reviewed publications or related types of professional scientific expression.

Using these criteria, the SSA Team identified 19 candidates for the lynx expert panel who were contacted to determine their interest and ability to attend the workshop (Appendix 4). Among those both interested in and able to attend the workshop, the team extended invitations to 13 candidates, 10 of whom ultimately participated as panelists and who together represent lynx expertise throughout the range of the DPS and in southern Canada. Experts who could not attend this workshop may provide their expertise later in the SSA process as peer review experts.

Preparing Experts

Before the workshop, the SSA Team contacted all lynx experts and other subject matter experts by email and phone to discuss their roles and, for some, their willingness to prepare and deliver subject matter or lynx population status presentations at the workshop. Correspondence with lynx and subject matter experts and other workshop participants explained the SSA framework and its application to the lynx DPS, the use of expert elicitation in SSAs, and the workshop's purpose, ground rules, and draft agenda.

At the workshop, the Service introduced the Lynx SSA Team, provided a brief overview of the SSA framework and its application to the lynx DPS, and outlined workshop objectives. Prior to elicitation exercises, subject matter experts presented information on the historic and current distribution of lynx in the contiguous U.S., regulatory mechanisms that apply to lynx on Federal lands, genetics considerations, lynx status and management in adjacent southern Canada, potential climate change impacts on boreal forest vegetation and snow conditions important to lynx, effects of forest management and policy on lynx habitat, and snowshoe hare ecology (see *Subject Matter Presentations*, below). After these presentations, lynx expert panelists provided updates on lynx populations and habitats, research efforts, conservation measures, and potential threats to lynx in each of the six geographic areas (Fig. 1). The subject matter and status-update presentations were intended to provide the expert panel with information that could inform their responses to elicitation questions and to ensure that the panelists shared a common understanding of the current status of lynx throughout the DPS. All workshop presentations are included in Appendix 5 and are accessible at the Service's Region 6 Canada lynx web page (http://www.fws.gov/mountain-prairie/es/canadaLynx.php).

Subject Matter Presentations

Canada Lynx Species Status Assessment, Expert Elicitation Workshop - Jim Zelenak, U.S. Fish and Wildlife Service, Montana Ecological Services Field Office, Helena, Montana

The objectives of this workshop are to (1) gather scientific information from experts on the current status, threats, and future viability of lynx populations in the contiguous U.S.; and (2) where empirical data are lacking, elicit expert knowledge, professional judgment, and opinion on the nature and magnitude of potential threats to DPS populations and the DPS as a whole. We need this information to complete a status assessment for the DPS that will be used by Service decision makers to inform recovery planning and other determinations the Service must make in accordance with the ESA. We have a court order to complete a recovery plan for the DPS by January, 2018, unless we determine that a recovery plan is not necessary (i.e., that the threat for which the DPS was listed has been adequately addressed and ameliorated and no new threats have been identified that pose an immediate or reasonably foreseeable risk of extinction). However, we are not here to make that determination or others regarding the ESA status of the DPS. Rather, we are here to understand the current status of lynx populations and habitats in the DPS and hear from experts on factors influencing the current status and future viability of those populations. The DPS was listed as threatened under the ESA in 2000 because of the inadequacy at that time of regulatory mechanisms in Federal land management plans to protect lynx and their habitats. The Service completed a recovery outline in 2005 and designated critical habitat for the DPS in 2006. In 2007, we clarified our determination of "significant portion of the range" of the DPS and withdrew the 2006 critical habitat designation. We revised critical habitat in 2009 and 2014 and, also in 2014, we received the court order to complete a recovery plan. The results of this workshop will contribute to the SSA, and the expert information gathered here will complement the best available scientific information that will be compiled and summarized in the SSA report. After it is peer-reviewed and finalized, the SSA report will be considered by Service decision makers to inform recovery planning and other determinations required under the ESA.

Historical Distribution of Lynx in the Contiguous U.S. - Dr. Kevin McKelvey, USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana

Understanding historical range is important because it provides context for modern conservation; however, historical data must be interpreted carefully because they may not be representative, are often unreliable, and their meaning may be unclear. This is especially true for rare animals like lynx, and even more so if they are easily mistaken for another more common animal, as bobcats are mistaken for lynx in the southern portion of lynx range. Because even relatively low identification error rates can lead to significant errors in determining distribution, it is important to rely on verified, and not anecdotal, occurrence records, when attempting to establish historical range. The issue is further complicated by the noted cyclicity in lynx population dynamics associated with snowshoe hare population cycles, which resulted historically in irruptions or pulses of lynx from Canada into the DPS when northern hare populations crashed. This can be described as a wave in which a large number of dispersing lynx intermittently flooded into the northern contiguous U.S. over the course of several years into a variety of potentially suitable and unsuitable habitats. As the irruptions waned (i.e., as the waves receded), lynx disappeared relatively quickly from areas of unsuitable or poor habitat, more slowly from areas of marginal or suboptimal habitat, and persisted (like permanent tide pools) in those areas with habitats and hare densities capable of supporting them over time. This yielded verified records in the contiguous U.S. in places that clearly cannot support lynx populations but, in other places where habitats are or appear to be suitable, it also confounds efforts to distinguish between those that have supported persistent lynx populations, those that may occasionally but not consistently support resident lynx ("winked off' more than "winked on" in a metapopulation sense), and those where dispersing lynx occurred regularly, if intermittently, but could not persist. Given these ambiguities, there remains irresolvable uncertainty about the historic distribution of resident lynx in the DPS. Despite this uncertainty, it appears that resident lynx naturally persist now in most areas that the available reliable data most strongly suggest historically supported resident populations in the contiguous U.S. (Maine, Minnesota, Montana, Idaho, and Washington). Several other areas may have historically supported populations but no longer do (with evidence most compelling for northern New Hampshire and Michigan's Upper Peninsula; less compelling for the Adirondack region of northern New York, northern Wisconsin, and northwestern Wyoming).

Canada Lynx Habitat Regulatory Environment - Scott Jackson, USDA Forest Service, National Carnivore Program Leader, Missoula, Montana

Before the lynx DPS was listed under the ESA, there was very little information available and little management direction for lynx habitats on national forests or other Federal lands. Given the uncertain status of lynx and lack of information on habitat relationships, an interagency Lynx Steering Committee was chartered almost immediately after the DPS was proposed for listing in 1998. The committee appointed the Lynx Science Team to assemble the available information on lynx and the Interagency Lynx Biology Team to develop a lynx conservation strategy applicable to Federal lands. In 2000, the Science Team published *Ecology and Conservation of Lynx in the United States* (Ruggiero *et al*. 2000), and the Biology Team completed the *Lynx Conservation Assessment and Strategy* (LCAS; Ruediger *et al*. 2000). The committee also directed the completion of the 1999 biological assessment (BA) in which the U.S. Forest Service (USFS) and Bureau of Land Management (BLM) evaluated potential impacts to lynx of management plans for 57 national forests and 56 BLM units and concluded that implementation of existing plans could result in some adverse effects to lynx. The BA recommended amending or revising management plans to incorporate conservation measures that would reduce or eliminate the identified adverse effects to lynx, and to consider the conservation measures identified by the Science Team and Biology Team, once finalized. In March of 2000, the DPS was listed as threatened due to the inadequacy of existing regulatory mechanisms, specifically the lack of guidance for conservation of lynx in national forest Land and Resource Management Plans and BLM Land Use Plans. In October 2000, FWS completed a biological opinion on the 1999 BA, concluding that if forest plans were revised or amended to incorporate the conservation measures in the LCAS, they would reduce or avoid the potential for adverse effects on lynx. Also in 2000, USFS and BLM entered into conservation agreements with FWS to guide management until plans could be amended or revised. By 2004, BLM revised plans in all units with lynx or potential habitat to incorporate LCAS guidance. By 2006, USFS similarly revised plans for national forests in the Northeast and Great Lakes. In 2007 and 2008, USFS formally amended plans for 18 national forests in the Northern Rockies and 8 in the Southern Rockies to address the risk factors identified in the LCAS and adopt management standards and guidelines. Currently, all national forests and BLM units with lynx or potential habitats are governed by plans that have adopted conservation measures identified in the LCAS, subsequent interagency conservations agreements, or by management direction that formally amended or revised land use plans and established standards and guidelines designed to apply the best available scientific information to avoid and minimize potential impacts to lynx. Future challenges include developing effective responses to larger, hotter, and more frequent fires and extensive insect outbreaks, and designing thinning and salvage harvest treatments conducive to creating habitat conditions favorable to lynx and hares.

Lynx Genetics Considerations - Dr. Michael Schwartz, USDA Forest Service, National Genomics Center for Wildlife and Fish Conservation, Missoula, Montana

Review of lynx genetic studies shows, despite some sub-structuring over distance, high gene flow across the continental range of lynx, likely because of high dispersal rates, large dispersal distances, and few geographic barriers to dispersal. Some research suggests that the Northern Rocky Mountains may provide some gene flow restriction in western Canada, as well as an “invisible barrier” to gene flow in eastern Canada south of James Bay/Hudson’s Bay that may be related to differences in snow conditions driven by large-scale climatic factors (e.g., the Pacific-North America and North Atlantic Oscillation climatic systems). North of the DPS, low levels of genetic substructure have been documented in populations in eastern Canada between populations north versus south of the St. Lawrence Seaway, and between island (Newfoundland and Cape Breton islands) and mainland populations. However, there is evidence of genetic interaction among even these relatively isolated eastern Canadian populations. Within the DPS, minor genetic sub-structuring has been documented among lynx subpopulations in western Montana. However, very low F_{st} values (a measure of the proportional reduction in heterozygosity due to population subdivision, with values near zero indicating high levels of gene flow and values approaching one indicating poor gene flow) suggest the absence of significant barriers to genetic interchange throughout much of the lynx range, including the DPS. Across 17 lynx populations in Alaska, Canada, and the contiguous U.S., $F_{st} = 0.033$, and the highest F_{st} for any two populations was 0.070 when lynx from the Kenai Peninsula in Alaska were compared to those in the Seeley Lake area of Montana. Lynx-bobcat hybrids have been documented in Minnesota, Maine, and eastern Canada, but not in the western part of the range. Hybridization does not seem to be a major issue, nor does it appear to be increasing despite significant increases in bobcat numbers in some parts of DPS range. Genomics research (the genetic mapping and DNA sequencing of sets of genes or complete genomes) on lynx would increase power and precision of genetic analyses and perhaps identify genes under selection at the periphery of the range. The goal for lynx in the DPS should be to conserve the genetic diversity currently represented in resident populations, recognizing that maintaining connectivity between DPS and Canadian populations is likely important to achieving that goal. The genetic variation at the edge of the range may be of value to future populations, especially as related to changing climate.

Lynx Distribution, Status, and Management in Southern Canada - Dr. Jeff Bowman, Ontario Ministry of Natural Resources and Forestry, and Trent University, Ontario

Lynx are managed provincially in Canada, with each province responsible for its own management program, harvest (trapping) policies, and conservation strategies. Data from registered trap lines show cyclic decadal peaks in the numbers of lynx harvested, and these align well with (and lag by one year) cyclic peaks in snowshoe hare indices. In western provinces (British Columbia, Alberta, Saskatchewan, Manitoba, Northwest Territories, and the Yukon), the magnitude of lynx cycles appears to have dampened dramatically after the 1980s-1990s, while eastern provinces (Ontario, Quebec, and Newfoundland and Labrador) have seen less dramatic declines in peak lynx numbers trapped. There is some evidence that hare numbers in the Yukon have not recovered to past levels after declines beginning in about 2000, and that hare numbers in southern Ontario have been low for the past 5-6 years. There also is indication that the range of lynx in eastern Ontario has contracted northward since the 1970s, and modeling suggests that this contraction is likely influenced by habitat loss perhaps related to changes in forestry practices and an increase in tolerant hardwoods replacing spruce-fir forests resulting from climate warming (Koen *et al*. 2014). This has been accompanied by reduced genetic heterozygosity (allele richness) at this margin of the lynx range. Recent studies also show some differences in functional genetic markers (unique alleles) in lynx south versus north of the St. Lawrence Seaway/River, suggesting the potential for evolutionarily significant differences in lynx in those areas (Koen *et al*. 2015, Prentice *unpubl.*). Research also suggests an “invisible” genetic barrier south of Hudson’s Bay likely related to climate-driven differences in snow conditions, which could be amplified in the future with continued climate warming. A few lynx-bobcat hybrids have been documented. Lynx are listed as endangered provincially in New Brunswick and Nova Scotia, which also have by far the highest numbers of bobcats, and where bobcat populations have been increasing since about 1990. Lynx are considered secure in all other provinces.

Seven Ways a Warming Climate can Kill the Boreal Forest - Dr. Lee Frelich, Director, University of Minnesota Center for Forest Ecology, St. Paul, Minnesota

Northern Minnesota is at the southern edge of the ranges of boreal forest tree species (balsam fir, white spruce, paper birch) and the northern extent of temperate forest species (sugar maple, red maple, red oak). A number of climate-mediated processes are likely to shift these ranges northward, potentially resulting in the complete disappearance of boreal forest from Minnesota before the end of the century. These include projected declines in snow depth, invasion of boreal forests by temperate species and a widening of the mixed forest ecotone, warming summer and winter temperatures, declines in boreal trees under both low- and high-emission climate scenarios, severe wind- and hail-producing thunderstorms (derechos) of greater extent and frequency, large wind-driven fires, heat and drought stress, increased insect infestations due to lack of extreme cold temperatures, and phenological disturbance. These processes, alone or in combination may result in gradual or relatively sudden conversion of boreal forests to temperate forests, savanna, or grassland at the southern edge of the boreal forest range. A mosaic of conversion mechanisms and rates of change will occur at landscape/ecoregion scales. With unmitigated climate change, Minnesota is likely to lose the boreal biome and about one-third of its native species, including lynx, possibly within the next 60-70 years.

Climate Change and Uncertainty: Implications for Canada Lynx Conservation and Management in the Contiguous U.S. - Alexej Siren, DOI Northeast Climate Science Center and University of Massachusetts Department of Environmental Conservation, Amherst, Massachusetts

Climate models are better at detecting long-term trends in temperature and precipitation than short-term climate variability. Generally, projections of precipitation are less robust compared to temperature, and within the lynx DPS units, projected trends in precipitation are more certain for winter than for summer. Consequently, the resulting model biases may affect climate projections. Global surface temperatures have increased steadily over the 20th century, especially since the 1970s, with an overall increase in winter temperatures in the U.S. These changes are most pronounced from the Northern Rockies to the northeastern U.S., where winter precipitation has also increased. However, the northwestern U.S. has experienced drier winters with less snow over the past several decades. Importantly, numerous studies have shown that Canada lynx distribution is related to snowpack characteristics (e.g., snowfall, density, and persistence), which may directly or indirectly affect lynx through 1) increased competition (exploitative and interference) with sympatric carnivores, 2) altering hare and lynx population cycles, and 3) reduced genetic diversity. Therefore, climate projections with a specific emphasis on winter climate are a valuable tool for assessing the long-term viability of lynx in the contiguous U.S. Below are the climate trends for the past several decades and end-of-century model projections for each of the DPS units; projections are multi-model means with the high emissions scenario (A2). In the Northeast, recent trends are toward reductions in snowfall, the number of snow-covered days per season, and the proportion of winter precipitation occurring as snow. Projections include increased winter precipitation, but with a lower proportion occurring as snow, and a decline in snowfall and length of snowpack coverage. In the Great Lakes region, recent trends indicate an increase in lake effect snow and longer snow seasons to the north. Winter precipitation is projected to increase throughout the Midwest, with a lower proportion occurring as snow, except that lake effect snow is projected to increase around Lake Superior and north of the eastern Great Lakes until 2050, and eventually decline towards the end of this century. Overall, models project a decline in snowfall and length of snowpack coverage by 2100 for the Midwestern region. The Northeast and Midwest DPS units are especially vulnerable to snowpack loss due to lack of elevational refugia. In the western DPS units and the Colorado population, recent trends show decreasing spring snowpack at lower elevations, an overall decline in snowpack by the latter half of the 20th century, and a lower proportion of winter precipitation occurring as snow. Projections include decreases in snowfall season and snowfall amount, fewer days with snowfall, and continued reduction in the proportion of winter precipitation occurring as snow. However, projections indicate that snowpack and winter severity may be less impacted in the Northern Rockies compared to other DPS units. In summary, model projections are not favorable for lynx within the DPS units, especially towards the latter half of the 21st century, with less severe winters and diminished snowpack characteristics that favor competing species.

Projected Climate-change Impacts on Snow, Vegetation, and Lynx Populations in the Western U.S. - Dr. Joshua Lawler, University of Washington, School of Environmental and Forest Sciences, Seattle, Washington and Dr. Chad Wilsey, National Audubon Society Science Division, New York, New York

Climate modeling suggests reductions in the amount of precipitation falling as snow and a shift from subalpine forest to temperate evergreen needleleaf forests in a generalized lynx range in the western U.S. Fire is projected to increase in both frequency and fire size, doubling by 2040 and tripling by 2080. Simulated lynx densities were projected for the 2020s, 2050s, and 2090s. Of 25 ecoregions included in the study area, 14 had simulated lynx populations greater than 0.10 individuals/100 km^2 across all time points. Of those, and across various Global Circulation Models (GCMs), 3 ecoregions had simulated increasing populations by the 2050s and 11 had declining populations. Populations were projected to continue increasing in the 3 ecoregions by the 2090s, while declines were projected to deepen in 8 of the remaining 11 ecoregions. Growing populations were projected to occur in the sparsely populated Fescue-Mixed Grass

Prairie, Middle Rocky-Blue Mountains, and Great Steppe ecoregions, whereas the largest proportional declines were projected to occur in the West Cascades, Pacific Northwest Coast, Northern Cascades, East Cascades – Modoc, and Aspen Parkland ecoregions. The study also looked at the effect of population cycling on projected changes and found that simulated declines differed more due to GCM model used than due to population cycling (i.e., modeling suggested lynx population declines were not strongly influenced by population cycles).

Forest Management and Lynx Habitat Trends - Dr. Erin Simons-Legaard, University of Maine School of Forest Resources, Orono, Maine

Lynx in Maine occur in the Northern Appalachian/Acadian Ecoregion where their distribution is governed by snowfall and extent of deciduous cover. The eastern spruce budworm (*Choristoneura fumiferana*) is endemic to forests in this region, and extensive outbreaks of this insect pest occurred in northern Maine in the 1970s-80s, resulting in millions of acres of spruce-fir die-offs, despite extensive aerial insecticide applications. For several decades, salvage logging via extensive landscape-scale clear-cutting occurred in impacted forests, until passage in 1989 of the Maine Forest Practices Act, which regulated clear-cut size, configuration, and regeneration. Regenerating clear-cuts became very dense stands supporting high densities of snowshoe hares. Although the Forest Practices Act reduced the amount of clear-cut harvest over the following two decades, overall harvest increased as partial-cut harvesting replaced clear-cutting. At the same time, land ownership patterns in northern Maine were shifting from large blocks of commercial timber interests to smaller blocks and more diverse land management goals, including development and financial investment, as well as some non-development easements (though these do not regulate forest management). The University of Maine modeled lynx habitat occurrence from snow track data, a series of Landsat satellite time-series imagery since 1970, and indices of hare densities for various stand ages post-timber harvest to model past, present, and future lynx occurrence in northern Maine. They found that the proliferation of regenerating partial-cuts produce lower landscape hare densities than regenerating clear-cuts from the 1970s and 1980s. Landscape hare densities will likely decline in the future as the clear-cut-era stands mature into less dense conifer stands, beginning about 35-40 years post-harvest. High-quality stands are being replaced by lower-quality regeneration of partial harvests. High-quality habitat for lynx/hares is currently about 8% of the northern Maine landscape. Model projections indicate it will decline to about 5% of the landscape by 2030, and then level off, and that the prevalence of partial-harvesting will lead to elimination of many areas with concentrated high-quality habitat and a lower future probability of supporting lynx.

Southern Snowshoe Hares: Updates, Questions, Forecasts - Dr. Karen Hodges, University of British Columbia Okanagan Department of Biology, Kelowna, British Columbia

Northern hare cycles are more variable than commonly portrayed in some literature, with questionable synchrony and variation in peak heights and amplitudes. Some southern hare populations (i.e., within the lynx DPS range) show “cycle-ish” dynamics and high densities, but variability in abundances is not obviously linked to forest stand type (thinned, unthinned, mature). Some areas of high hare density are occupied by bobcats instead of lynx (e.g., the Tally Lake area of the Flathead National Forest in Montana). Hare densities in the western contiguous U.S. differ substantially across regions and landscapes. For example, within the GYA, hare densities varied from very low (0.2 hares per hectare) in Yellowstone National Park to very high (0.5 - 1.7 hares/ha) in the Wyoming Range south of the park. Hare densities also vary in the eastern part of the lynx DPS, with ranges from 0 - 1.8 hares/ha in Maine and, in Minnesota, densities of 0.64 hares/ha in the northeast part of the state (which supports resident lynx) and 0.35 hares/ha in Voyageurs National Park (which does not support resident lynx). Landscape attributes (e.g., tree densities and moisture gradients) also influence stand quality for hares. Hare population dynamics (cyclicity, synchrony, amplitude, and peak densities) also vary regionally. Forest management that reduces stand structure reduces hare abundances. For example, hares declined after experimental precommercial thinning in Montana, and, in Quebec, hare densities increased with time since commercial thinning, harvest, and fire. Fire destroys hare habitat temporarily, but hares return to burned areas as soon as favorable habitat conditions return. Post-fire hare densities also vary regionally; in stands burned by large fires in 1988, hare densities by 2007 were higher in Glacier National Park than in Yellowstone National Park. Hare densities necessary to support resident lynx remain poorly understood but appear to vary regionally, as do lynx diets and home range sizes. If southern boreal/montane forests are lost, hares will decline. Fire, timber harvest, and thinning will result in fewer hares, at least temporarily, and the impacts of post-fire salvage logging are unknown. Understory cover and browse are very important, but we know little about the influence of shrubs or snow on hares. Like lynx, hares in the DPS are at the southern extent of their continental range. Also like lynx, hares show high gene flow across most of the northern range in Canada but lower gene flow (higher genetic structure) in the southern part of the range, with some lineages potentially at risk of genetic drift. Climate-mediated increases in fires and insect outbreaks and changes in forest regeneration may alter hare habitats and, thus, hare distribution and abundance. Climate change may also affect hare vulnerability to predation by creating a mismatch between pelage color, which is controlled by photoperiod, and their surroundings (e.g., reduced snow season resulting in white hares on dark forest floors). It may also alter predator communities, with uncertain impacts on hare populations. Continued research is needed to better explain regional variation in population dynamics and peak abundances, to predict post-fire recolonization and densities and responses to climate change, and to better understand links between physiology and demography (e.g., predation stress and reproduction).

Lynx Status Update Presentations[1]

Status of Lynx in Maine - Jennifer Vashon, Maine Department of Inland Fisheries and Wildlife, Bangor, Maine

Much of the current lynx habitat in Maine was created from extensive harvests to salvage spruce budworm-damaged forests during 1970-1985, and the amount and distribution of high-quality lynx/hare habitat are likely greater now than historic conditions. Many stands were treated with herbicides to create extensive regeneration of spruce and fir. Analysis of Forest Inventory and Analysis (FIA) data indicates that half of the 3 million forested acres of spruce-fir in northern Maine is currently sapling stage that should provide lynx with high quality foraging habitat. Also based on FIA data, the amount of dense spruce-fir (supporting the highest hare densities) increased from 700,000 acres in 2006 to 805,000 acres in 2010. The Maine Department of Inland Fisheries and Wildlife (MDIFW) conducted a telemetry study of lynx from 2000-2011 in a study area with extensive areas of regenerating spruce-fir stands in northwestern Maine and found that lynx had relatively small home ranges. Lynx strongly selected these high-quality hare habitats in former clear-cut areas. Although hare densities declined from 2 hares/hectare to 1 hare/hectare mid-way through the study, lynx did not increase their home range sizes or alter their habitat use. Reproduction declined initially after hare populations declined, but later recovered, with all females producing litters. An average of 65% of females bred each year throughout the study. Litter sizes ranged from 1 to 5 and averaged 2.63 kittens/breeding female. Kitten survival remained high (averaged 78%). Densities of 4.5 adults and 5 to 9 kittens were observed in 100 km^2 areas. Based on estimates of occupied habitat and home range information, MDIFW estimated there were between 750 and 1,000 lynx in northern Maine in 2006, and more than 1,000 lynx in 2015 (or at least more animals than 2006). Indices (number incidentally trapped, observed, or killed on roads) have increased, suggesting there are more lynx than in 2006, and the distribution of the population also appears to be expanding. MDIFW initiated a third round of periodic lynx snow track survey in 2015 that support increased populations and expanding range. Additional surveys are planned in 2016 and 2017 to update estimates. Although a model by the University of Maine suggests the effects of the Maine Forest Practices Act could lead to a decrease in lynx habitat, thus far, it does not appear that lynx have declined in response to aging clear-cuts and the prevalence of partial harvests resulting from the Act. A budworm outbreak is expected in the near future that will also impact future amounts of habitat for lynx and snowshoe hare. MDIFW provides landowners with descriptions of lynx-hare habitat for their management plans through published peer-reviewed papers and reports on lynx status and habitat use in Maine and consultation.

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[1] These are summaries of status updates presented by lynx experts for each of the geographic units in the DPS. Summaries were written by the Lynx SSA Team based on the presentations and notes submitted by expert presenters and on the notes taken at the workshop during presentations. Experts reviewed drafts of these summaries and provided clarifications/ corrections if needed, which were incorporated into the final summaries.

Canada Lynx in Minnesota - Dr. Ron Moen, Natural Resources Research Institute, University of Minnesota Biology Department, Duluth, Minnesota, and Susan Catton, USDA Forest Service, Superior National Forest, Duluth, Minnesota

Prior to 1965, lynx in Minnesota were unprotected, had a bounty placed on them, and were overexploited by trapping. From 1930-1977, harvest in Minnesota was twice that of Montana and 40 times that of other states. In 1976, State protection was provided in the spring and summer months, and in 1984 the trapping season was closed. In the 1990s and when listed under the ESA in 2000, it was unknown if lynx in Minnesota were residents or migrants from Canada, but now it is known that the Minnesota lynx population consists of both residents and migrants from Canada. Since then, there have been hair snare and snow-tracking surveys, DNA analyses, and a multi-year telemetry project – none of these monitoring efforts were designed to estimate densities or abundances of the species. However, as of 2015, it is thought that there are somewhere between 50 and 300 lynx in Minnesota (this expert later refined the range as 50 - 200 lynx, as indicated in the summary presentation preceding the graphing exercise below), with the core habitat in the arrowhead region of the state (St. Louis, Lake, and Cook counties), although there have been verified and probable lynx sightings elsewhere in the state. At least 5 of 27 adult lynx radio-collared in Minnesota were later legally trapped in Ontario, and other collared lynx did not return from Canada, therefore their fates are unknown. Telemetry data showed that about half of males radio-marked in Minnesota moved back-and-forth across the border, traveling at all times of the year; that Minnesota females that dispersed into Canada tended not to return to Minnesota; that males had much larger home ranges (267 km^2) than females (21 km^2); and that females with kittens had the smallest home ranges. About half of the mortality of collared lynx was from vehicle collisions, incidental catch, illegal kills, or unknown causes. Moen *et al*. (2008) documented 10 den sites and showed that denning habitat is not limiting in Minnesota. Since 2000, incidental take of lynx tracked by the USFWS Twin Cities Field Office has ranged from 0-14 per year and included vehicle (car and train) collisions, gunshot, incidental trapping, and unknown causes. Approximately 50% of reported take was of incidentally trapped lynx, about half of which were released alive. Home range analyses showed mean distance to nearest linear feature is approximately 200m, suggesting that lynx do not avoid roads. Bobcat harvest data show a concentration of bobcats adjacent to the core of the lynx range. The IPCC SRES A1B Scenario climate change model (Gonzalez *et al*. 2007, p. 14) shows snow conditions potentially suitable for lynx throughout the northern half of Minnesota to the end of this century; however, the snow and/or biological assumptions in the model need work, because it predicts a range for lynx that is larger than the current suitable range based on snow depth. Other climate modeling (e.g., Morgan, in prep.) suggests that suitable snow-depth range will shrink significantly by 2055, be limited to extreme northeastern Minnesota by 2070, and may be entirely absent from the state by 2095. Since 2000, the Superior National Forest (SNF) and others have identified 268 unique individual lynx (47% Female, 53% Male) from 1,306 DNA samples, primarily from SNF lands. These samples also documented 13 unique individual lynx-bobcat hybrids (5 Female, 8 Male). 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. The SNF annually documents 3-5 family groups and is working with

North Carolina State University and the Twin Cities Field Office on a study of the distribution of lynx that can be used to inform future study designs aimed at monitoring lynx occupancy and designing more intensive studies to estimate abundance.

Current Distribution, Status, and Threats to Canada Lynx in Montana and Wyoming - Dr. John Squires, USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana

Northwestern Montana - This area is believed to support the largest lynx population in the western U.S., but minimum population size has not been calculated. The Forest Service's Rocky Mountain Research Station in Missoula initiated a lynx research program in 1998 to investigate lynx resource and prey selection, competition, activity patterns, detection and monitoring, and connectivity. From 1998 to 2007, researchers 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. From 1999-2007, litter sizes averaged 2.24 kittens/litter (N = 33) in the Seeley Lake area (the central portion of this geographic unit) and from 2003-2007, 2.95 kittens/litter (N = 22) in the Purcell Mountains (the northwestern portion of the unit). In Seeley Lake, 61% of breeding-age females (N = 52) produced kittens; in the Purcells, 83% of females (N = 28) produced kittens. Recent research (Kosterman 2014) suggests kitten production is correlated positively with mature forest connectivity and negatively with fragmentation in female home ranges. 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. There was no evidence of cyclicity in these vital rates, and no indication of irruptions of lynx into this unit from Canada after the 1980s. Starvation, predation by mountain lions, and human-caused deaths each accounted for roughly one-third of documented sources of lynx mortality. Population viability analyses yielded population growth rates 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). The distribution of lynx in this unit appears to have contracted recently; lynx were documented in the Garnet Mountain Range in the southern portion of the unit from at least 1980 into the early 2000s, but in 2010, extensive research trapping efforts yielded only two males, and snow-track and camera-trap surveys in winter 2014-2015 detected no lynx. Genetic analyses revealed fine-scale genetic sub-structuring among the Garnets, Purcells, and Seeley Lake subpopulations, suggesting some level of relative isolation among lynx in those areas. Most lynx habitat in this unit occurs on Federal lands (USFS, BLM, NPS). Recent conservation land purchases substantially increased protection of lynx habitat in the Seeley Lake core area. The extent of fire in this area has increased, with over one million acres burned in 2000-2013. Forest management (timber harvest, silviculture, and fire management) can have negative, neutral, or positive impacts on lynx habitat; current research is investigating lynx response to management actions.

Wyoming/GYA – The long-term persistence of lynx in the GYA is unknown, but early records from Yellowstone National Park documented lynx presence in the 1920s-30s, and more recent (2001-2004) surveys in the park documented several lynx and evidence of reproduction on the east side of Yellowstone Lake. South of the park, lynx were also detected reliably in the late

1990s-early 2000s in the Union Pass and Togwotee Pass areas of the Wyoming Range in the Bridger-Teton National Forest. Several lynx released in Colorado (1999-2006) dispersed to the GYA and occupied home ranges (including males and females with overlapping home ranges) in areas of the Wyoming Range previously occupied by "native" resident lynx. Recent (2005-2010) research trapping and survey efforts in the Wyoming Range have detected only Colorado-released lynx, and the current status of lynx in the GYA is uncertain but believed to be at low numbers based on on-going surveys. In addition to fire and forest management (as described above for northwestern Montana), oil and gas exploration and development may pose a potential risk to lynx and habitat in the Wyoming Range.

Lynx in Washington: Current Status and Potential Threats – Dr. Benjamin Maletzke, Washington Department of Fish and Wildlife, Olympia, Washington

Lynx in Washington were State-listed as threatened in 1993, but with recent large-scale impacts to lynx habitats and likely declines in lynx numbers, upgrading to State-endangered may be justified. The Washington Department of Fish and Wildlife completed a lynx recovery plan in 2001, and the Department of Natural Resources completed a habitat management plan for its lands in 1996, which it revised in 2006. The majority of lynx habitat in Washington occurs on public lands including State Forests and National Forests. Although individual lynx are occasionally documented in the northeastern part of the state, only the Okanogan area (eastern Cascade Mountains abutting the border with Canada) in the north-central part of the state has consistent records and evidence of a resident breeding population. In terms of the ESA's five listing factors, over-utilization, disease/predation, and inadequacy of existing regulatory mechanisms are not issues for lynx in Washington. Lynx trapping was prohibited in 1991, and only live-trapping is allowed for bobcats, so there is little chance for incidental trapping. There is no documented disease and little evidence of predation (though these could occur/increase with climate change). With ESA and State listings, critical habitat designation, and State recovery and State and Federal habitat management plans in place, regulatory mechanisms appear adequate. Recently, much lynx habitat has been lost, at least temporarily, to frequent large-scale fires and insect outbreaks, and climate change may pose additional (or exacerbate existing) threats to lynx and habitats in Washington. From 1990-2002, there were about 2,600 km^2 of lynx habitat in the Okanogan (Eastern Cascades) area, and female home ranges were estimated at 38 - 41 km^2, suggesting the potential to support roughly 90-115 resident females (home ranges include "matrix" or non-habitat). By 2014, habitat had been reduced by fire to about 1,600 km^2, and habitat loss and fragmentation resulted in female home ranges increasing to an estimated 91 km^2, with a potential to support roughly 27 resident females. Although areas impacted by fires and insects should regenerate to hare/lynx habitat, it may take 35-40 years or more for that to happen. Climate change will likely reduce snow depth, condition, and persistence, potentially influencing interspecific competition. It also may cause temperature- and precipitation-driven changes in vegetation and increased fire frequency, size, and intensity, resulting in further reduction, fragmentation, and isolation of suitable habitats and impacts to prey abundance. Connectivity between the Okanogan area and lynx populations and habitats in Canada seems adequate; it is more tenuous in the northeastern part of the state, where cross-border populations/habitats in Canada are smaller and potential corridors more constricted. It is also possible that legal trapping in southern British Columbia could limit immigration into Washington's lynx population and be a source of mortality for lynx dispersing from Washington into Canada. Potential management and recovery actions could include resuming surveys and monitoring efforts, reviewing current State, Tribal, and Federal management actions to see if they can be more "lynx-friendly," conducting population viability analyses to estimate probabilities of persistence over various time periods, coordinating with British Columbia on cross-border lynx conservation efforts, evaluating the need and feasibility of augmenting female lynx in the Okanogan and reintroducing lynx to the Kettle Crest, up-listing lynx in Washington to indicate the current status and severity of threats, and seeking collaboration and funding to support the measures above.

Status of Lynx in Colorado - Dr. Jake Ivan, Colorado Parks and Wildlife, Fort Collins, Colorado

Lynx in Colorado were State-listed as endangered in 1973. Based on statewide surveys conducted in 1978-1997 that found some possible lynx sign (tracks), the State concluded that if lynx were present, too few individuals remained for a viable population and that natural recolonization was unlikely due to geographic isolation. The State initiated a lynx reintroduction program, releasing 218 lynx from source populations in Alaska and Canada from 1999 to 2006. All animals were released into the San Juan Mountains in the southwest part of the state. Many stayed there and used the area heavily; many others established home ranges in the Sawatch Range in the central part of the state, where the bulk of historical records occurred. Although post-release mortality was initially high, it decreased after release protocols were modified and among lynx after they'd been on the ground a year. Mean annual survival was 0.93 for lynx that stayed within the San Juan Mountains core-release area, and 0.82 outside of it. The first den was located in 2003, and 48 dens were subsequently documented in Colorado through 2010, including a third-generation of Colorado-born lynx. The reintroduced population displayed reproduction similar to other areas in the DPS in some regards (e.g., mean litter size was 2.75 kittens), and lower in others (e.g., mean percentage of females that produced kittens was 24% [range = 0% - 46%])[2]. A deterministic model that uses survival estimates and reproduction data from ten years of monitoring reintroduced lynx and assumes that reproductive parameters observed during that time would repeat each decade shows a slightly increasing trajectory through time. Although current population size and survival rates are unknown, photos of females with kittens in 3 sampling units during occupancy monitoring in the San Juan Mountains in 2014-15 and capture of young and unmarked (i.e., "new") lynx during research efforts in 2010-15 provide evidence of continued reproduction. Potential threats to lynx in Colorado include climate change, bark beetle outbreaks, fire, increasing human recreation, and vulnerability to vehicle collisions and disturbance from highways. Climate modeling in 2014, based on the RCP6 (2nd-highest) emissions scenario, suggests that by mid-century temperature will increase by 2°C, precipitation will decrease in the San Juan and other southern mountains, and that spruce-fir habitat will migrate upslope, lagging climate conditions by 50-100

[2] These data were provided by the presenter after the workshop but were not part of the original workshop presentation.

years. Based on this, the overall vulnerability of spruce-fir in the state is considered moderate at mid-century. As of 2014, over 4 million acres of potential lynx habitat has been impacted by bark beetle outbreaks; however, lynx and hares continued to use impacted areas, even when beetle impacts are severe. Red squirrel use declined in areas that were heavily impacted by beetles. Large fires also have impacted lynx habitat, and as elsewhere, fire size, frequency, and intensity are expected to increase with climate change. A cursory, pre-analysis review of location data suggests that lynx make use of landscapes in which heavy winter recreation occurs. However, use of developed ski areas is light, and outside of ski areas, heavy lynx use tends to occur in thick timber that is not used by snowmobilers and other backcountry users. Finally, lynx frequently crossed 2-lane paved highways in home ranges (0.6 crossings/day), more often at dusk and night, coincident with lower traffic volumes, and usually at forested crossings. Recent results from a new large-scale monitoring program indicated that lynx occupied a similar proportion of the landscape in the San Juan Mountains during winter 2014-15 as they did during winter 2010-11.

Expert Elicitation Process

All questions posed to the 10 lynx expert panelists were framed in the context of the 3Rs, a driving principle for evaluating viability under the SSA framework. In questioning, we used a modified Delphi method (e.g., MacMillan and Marshall 2006), which involves eliciting individual responses/scores, exploring response rationale and differences in expert judgment through guided discussions, then allowing experts to reconsider their scores in light of those discussions if they so desire.

In our implementation of the modified Delphi approach, panel members were first asked to respond individually to a particular question and indicate their level of confidence in their response. We then collated and noted the range of responses, which became the mechanism for follow-up discussion. In collating responses, we used a simple numeric coding system rather than the experts' names to provide for a reasonable level of anonymity. We noted where there was high congruence among responses, as well as low congruence and outlying responses. By asking for experts to voluntarily provide their reasoning for particular responses, we were able to delve into the basis for varying opinions. After the discussion period, experts were given the opportunity to revise their scores.

In addition to elicited responses to each question, we received substantial feedback from the experts on definitional issues and the validity of the questions themselves; we revised the questions as needed following these discussions. In the case of a revised question, scores were elicited again following the revision. The second round of scoring was displayed for experts, with a closing opportunity for comment, discussion, or score revision.

All panel members were encouraged to respond to each question but also given the option of abstaining from responding to a question if they felt it was beyond the bounds of their expertise. With few exceptions, all 10 expert panelists responded as requested to every question.

Instances where experts either chose not to reply or otherwise replied in a manner differing from the expected form of response to the question are noted in the responses below.

Lynx Status: Expert Elicitation and Responses

Questions for experts were scripted by the Lynx SSA Team prior to the meeting to facilitate discussion of lynx ecology among the experts, solicit their professional opinions, and to help the Service gather and synthesize biological information for use in the SSA, particularly where empirical data are lacking in the published literature and projecting habitat and population conditions into the future is needed. Because of the uncertainty of quantifying the population status and other aspects of lynx biology, the Service and facilitators decided to generate a series of discussion questions with quantifiable responses (scores) concerning the redundancy, resilience, and representation (3 Rs) of the DPS. Although scores provided a starting point for discussion among experts and are quantified, analyzed, and summarized as appropriate in the following sections of this report, the Service also places high value on the content of the discussion among experts. Therefore, both the analyses of scores and summaries of the discussion content are presented and will be considered during development of the SSA, noting that both were integral to the expert elicitation process.

The types of questions and the format of responses differed based on the information needed to inform the status assessment, and the best way to capture the information relevant to the question being asked. For example, responses were requested in the form of lists, when a set of influences was desired, in the form of a 4 point elicitation (e.g., the most likely, high, and low end of a range, and confidence that the range contains the true value) when an uncertain quantitative value was desired, in the form of graphed trajectories when probabilities of persistence over time were desired, and other forms as necessary (see questions below). Experts submitted their scores independently via submission sheets (sticky notes, index cards, graph paper, etc.) with their ID numbers. Note takers recorded and displayed scores to assist discussion. Facilitators and other members of the SSA Team then asked directed questions to clarify responses from the panelists as needed. Following each round of discussion and clarification, the panelists were provided the opportunity to update their response if desired and the second round of responses were collected and recorded. The final responses are the only responses reported here. The range of individual responses that we received was not combined (e.g., averaged or otherwise) in any way that would obscure or conceal individual responses, and the final scores for each panelist were recorded if the response was revised.

We present the results of the expert elicitation below under the headings of representation, redundancy, and resilience. Under each heading, the following is provided: the definition of the viability category (3 Rs) under consideration, the question(s) asked of the expert panelists, response type (i.e., the form of the response requested of the experts), question clarification (i.e., a narrative description of any additional information provided to the experts by the facilitators for clarification as the questions were asked), expert responses, and notes from the discussion.

Expert Responses

Representation

<u>Definition</u> - ***Representation*** contributes to the adaptability and evolutionary capacity of a species over time, to accommodate long term issues like climate change. The breadth of genetic ecological, demographic, and behavioral diversity across a species' range may contribute to its capacity to adapt over time. Measures of genetic and life history variability among populations, distribution of populations across a range of ecologically diverse locations or niches, etc., are useful proxies to measure. Consider needs for establishing or reestablishing populations in unoccupied habitat that may be necessary or suitable for species adjustment to climate change or other stressors, including the need to replace former populations in no longer represented ecosystems.

Representation Questions

1. Are any of the geographic units susceptible to genetic drift on a scale that would limit genetic viability? If yes, which geographic units?

Response Type: Experts supplied a written response of "yes" or "no," with a yes answer accompanied by a list of susceptible geographic units.

Expert Responses: Five experts responded that none of the geographic units are susceptible to meaningful genetic drift, two experts abstained from answering, and three experts responded that there are geographic units that are susceptible to such genetic drift. Among the latter, one expert responded that the Colorado geographic unit is susceptible over a long period of time, and the other two experts responded that both the Colorado and GYA geographic units are susceptible to genetic drift.

Discussion Points Following Initial Responses: It wouldn't take many immigrating lynx to provide adequate genetic diversity to prevent genetic drift. One reproductively successful immigrating lynx every 5 to 10 years per geographic unit is likely sufficient to prevent genetic drift. Most experts believed there was a low likelihood that even the smaller lynx populations (GYA and Washington) or those in more isolated geographic units (Colorado and GYA) are vulnerable to genetic drift at a scale that would impact viability, though several experts felt that both the GYA and the western Colorado units could experience meaningful drift in the absence of immigration or augmentation. Overall, most experts felt there is a low risk of genetic drift being a problem for lynx in the DPS.

2. Are there locations from a lynx perspective that have unique habitat conditions relative to other areas in the lynx range that are necessary to foster future adaptive capacity of the DPS? If yes, where?

Response Type: Open discussion. No response forms were submitted, but notes were taken on the discussion that followed.

Question Clarification: The experts required some clarification of terms and the intention of this question to respond. Facilitators read the working definition of representation (above), which previously had been provided to the experts. Experts then discussed representation across the lynx DPS from an adaptive capacity perspective.

Expert Responses: The response was an open discussion captured below.

Discussion Points Following Initial Responses: Maintaining genetic variability is important for adaptive capacity. If uncertain about the capacity for lynx to adapt, then experts encouraged that all populations (and hence the genetic variation within each) be maintained. Experts indicated that it doesn't appear that any U.S. population is more or less important to maintain than the others because of relatively similar ecological settings and the generally low level of genetic differentiation across the DPS. Summary: Experts discussed that maintaining representation in the DPS could best be achieved by retaining current DPS populations, maintaining connectivity between DPS and Canadian lynx populations, conserving the genetic diversity currently represented in DPS, and avoiding impacts that could facilitate or increase the potential for or likelihood of genetic drift.

It was also noted that lynx north of the DPS in some parts of eastern Canada (in New Brunswick and Quebec south of the St. Lawrence Seaway and on Newfoundland Island) have some unique alleles, including at functional genes, and should be preserved. Lynx in these areas are relatively more isolated than lynx elsewhere in Canada. Lynx south of the St. Lawrence are separated from lynx to the north by the seaway itself, which historically froze over during winter but which is now kept open to facilitate maritime shipping, perhaps reducing the level of genetic exchange between lynx on opposite sides. Lynx on Newfoundland Island are separated from lynx in mainland Labrador and Quebec by the 15- to 60-kilometer-wide Strait of Belle Isle. Despite the relative isolation of these populations, genetic evidence indicates some interchange between lynx south and north of the St. Lawrence and between Newfoundland Island and mainland populations. Eastern Canadian populations north of the St. Lawrence may have slightly different genetic composition than lynx in the Maine geographic unit.

Redundancy

<u>Definition</u> - ***Redundancy*** contributes to the ability of population types to withstand catastrophic events (hurricanes, wildfires, etc.). The number and distribution of populations of each representative type contribute to the retention of various representative types despite catastrophic events by ensuring that the loss of a population doesn't lead to the loss of representation.

Redundancy Questions

1. List the factors/catastrophic events that could functionally extirpate an entire geographic unit.

Response Type: Each expert supplied a written list submitted via index card of the factors/catastrophic events.

Question Clarification: Three issues required clarification prior to obtaining responses to this question. First, we initially asked about eliminating a "population" rather than a geographic unit. Because some of the geographic units may support several relatively isolated subpopulations, experts questioned whether we meant individual populations or subpopulations. We clarified that we are evaluating the likely persistence of resident lynx populations in each of the six geographic units that currently support or recently supported them; therefore, we are interested in the likelihood that a catastrophic event could result in the extirpation of resident lynx from the entirety of any of the geographic units. Second, we were asked if extirpation meant the complete loss of all lynx from a unit. We clarified that we wanted to know if lynx could be "functionally extirpated" from any geographic unit, with functional extirpation described as the loss of the unit's ability to support a resident breeding population(s) of lynx. Third, experts were not clear what an "event" entailed. After discussion, it was agreed that an event was defined as a single occurrence of some form, such as a fire, drought, hurricane, etc., that occurs over a relatively brief period of time, rather than a series of smaller cumulative events (e.g., a series of climate change-associated occurrences of fires or insect outbreaks over the course of a decade) causing a cumulative catastrophic result.

Expert Response: Six of the ten experts did not list any catastrophic events that could result in the functional extirpation of lynx from any entire geographic unit. Three of the experts listed multiple catastrophic events they felt could result in at least temporary functional extirpation of lynx in a unit. Among these, two of the experts listed fire, three listed disease, one listed insect outbreak, and one listed a failure of winter conditions due to a combination of heat or drought conditions. One expert listed geographic unit-specific events, namely fire or insect outbreak for the Washington geographic unit, insect outbreak in Maine, and either insect outbreak or fire for one of the Minnesota geographic unit's groupings of individuals, but not all.

Discussion Points Following Initial Responses: Experts were told that climate change was not considered a catastrophic event because it is both a driver of events and influences severity, rather than being an event itself as defined above. Experts discussed the possibility that the Washington geographic unit, because of its relatively smaller size and history of recent extensive fires in lynx habitat, may be at risk of functional extirpation from multiple catastrophic events; disease, fire, and beetle outbreak were all mentioned as possible events. One expert suggested that the Minnesota geographic unit could potentially be eliminated by a very large fire, although there was a low probability of this occurring. Experts expressed some uncertainty whether fire could occur at the severity and scale sufficient to eliminate an entire geographic unit; however, a series of fires over a short time period may have the potential to cause functional extirpation of lynx from a geographic unit or significantly reduce the number of resident lynx it could support, at least temporarily.

2. Could any of the catastrophic events listed in response to redundancy question 1 eliminate all 6 geographic units simultaneously?

Response Type: Each expert supplied a written response of “yes” or “no.”

Expert Response: All experts answered “no.”

3. What is the probability (expressed as a percentage) that any single geographic unit could be eliminated by a single catastrophic event in the <u>next 10 years</u>?

Response Type: 1-point elicitation. Each expert supplied a written response of X%.

Question Clarification: In response to the discussion around question #1, which resulted in the inclusion of question 3, this question was modified from its original script to include a 10-year time frame (underlined).

Expert Responses: All responders gave a relatively low probability ($\leq$ 10%, median of 1%) that any single geographic unit could be eliminated (resident lynx functionally extirpated) by a single catastrophic event in the next 10 years (Figure 2).

4. What is the percent likelihood that a series of catastrophic events within the next 10 years could cause functional extirpation of one or more lynx geographic units?

Response Type: 1-point elicitation. Each expert supplied a written response of X%.

Question Clarification: This question was developed after discussion of question 3 to capture the possibility of functional extirpation of lynx from geographic units due to a series of catastrophic events over a relatively short time rather than a single event that occurs at one point in time.

Expert Responses: The percent likelihood ranged from 0.5% to 60%, with a median response of 7.5% (Figure 2). Expert responses indicated a higher probability <u>of a series of catastrophic events over 10 years</u> resulting in functional extirpation than a single event in the next 10 years, as in question 3.

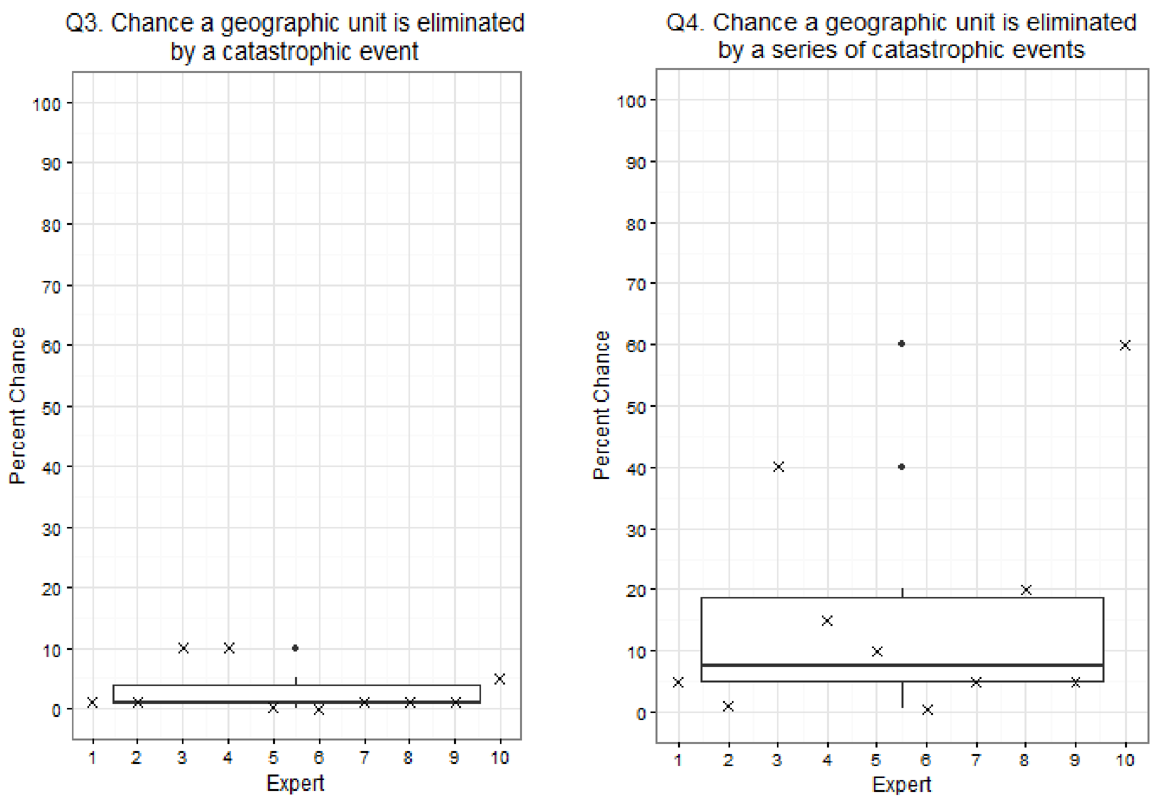

Figure 2. Individual scores and summary boxplots of the percent chance that a geographic unit is eliminated by a single catastrophic event (question #3, left) or a series of catastrophic events (question #4, right) in the next 10 years. Note: This and all subsequent figures below were generated using the statistical software R (Appendix 6).

In Figure 2, individual responses to a single catastrophic event were 0.01%, 0.1%, five responses of 1%, 5%, and two responses of 10%. Individuals responses to a series of catastrophic events were 0.5%, 1.1%, three responses of 5%, 10%, 15%, 20%, 40%, and 60%). Boxplots illustrate response mean values (bold black lines), the 25% and 75% quartiles (upper and lower bounds of boxes), and the highest and lowest values within 1.5 times the quartile range ("whiskers" external to boxes). In this analysis, responses beyond the ends of the whiskers (outside 1.5 times the quartile range) are considered outliers and plotted as points beyond the ends of the whiskers (i.e., experts 3 & 4 in Q3 and experts 3 and 10 in Q4, as indicated by the points plotted between experts 5 and 6). The individual expert responses used to produce the boxplots are indicated by x-marks. Boxplots are provided as a summarizing visualization to aid comprehension of the experts' responses and their range, and the summary values are presented in this context and not intended for use outside of the context of the full set of responses.

Discussion Points Following Initial Responses: One expert noted that the probability of extirpation in any one of the 6 geographic units is greater than the probability of a single specific geographic unit being extirpated. Also, any combination of a series of events over a decade increases the likelihood of extirpation in any one geographic unit relative to the probability of extirpation due to a single event.

Although median probabilities of extirpation were low, experts felt the geographically smallest unit (Washington) and those units believed currently to support the fewest resident lynx (GYA, Washington, and Minnesota) were the most vulnerable geographic units when scoring this exercise. Fire, drought, and beetle kill were the most frequently mentioned events that were considered by the experts when answering this question. Some experts felt that these geographic units may be susceptible to such a scenario because of small geographic and/or population sizes and distribution. In particular, it was noted that this past year there were many fires in lynx habitat, especially in Washington, and another year with similar fire impacts, or a few such fire years in a 10 year period, could lead to extirpation of lynx in the Washington geographic unit. An expert noted there currently may be as few as 24 remaining females in Washington and that with fewer individuals in this area it would result in a higher probability of at least temporary extirpation. Experts noted that fire disturbance data are likely available that could be used to model the likelihood of future fire impacts to each geographic unit.

Experts with outlier responses provided their rationales. Experts having the lowest scores believed that even the smallest geographic units would have only a low probability of extirpation in the next decade - that the time frame under consideration was very short.

5. What length of time would be required for a geographic unit eliminated by a catastrophic event to reestablish naturally?

Response type: 4-point elicitation. Each expert supplied a written response in years for the longest, shortest, and most plausible time periods for reestablishment of a resident lynx population within a geographic unit following functional extirpation. They were also asked to indicate their confidence, as a percentage chance, that the true amount of time necessary for reestablishment would fall between the shortest and longest plausible time periods provided.

Expert Responses: The responses to each of the points elicited are shown below in Table 1. Two experts provided additional information beyond the 4 points elicited when responding. One presented two scenarios, one in which connectivity is intact and the habitat was damaged by the catastrophic event (e.g., insect outbreak or fire) which would require habitat regrowth first, and the second in which the habitat remained present. In the case of habitat being present the most likely time period response was less than 10 years. In the habitat elimination scenario the expert felt given climate changes to habitat that the geographic unit would not re-establish. The second expert responded by geographic unit, with the exception of the Minnesota geographic unit for which there was no response. Their responses are summarized in Table 1 using the overall longest and shortest responses as well as the average of the most plausible time (see footnote 3).

Table 1. Expert responses regarding the natural reestablishment time in years for a geographic unit after extirpation by a catastrophic event.

Expert #	Reestablishment Time in Years			Percent Confidence in Range[3]
	Shortest Plausible Time	Most Plausible Time	Longest Plausible Time	
1	10	40	100	50%
2	15	100	300	80%
3	15	35	60	5%
4[4]	1, will not reestablish	<10, will not reestablish	will not reestablish	100%
5	25	50	100	75%
6	20	30	50	90%
7	15	20	25	90%
8	15	50	will not reestablish	40%
9	20	30	100	50%
10[5]	15	55	200	50%

Expert responses are also visualized in Figure 3 and Figure 4 below. The raw responses are visualized in box plot form to aid communication of the results (Figure 3). Confidence ranges provided in a four point elicitations enable expert responses to be rescaled to produce a common confidence bound across experts using linear extrapolation (e.g., McBride *et al*. 2012). We calculated the 95% confidence interval for the shortest and longest plausible time periods for each expert (Figure 4). In cases where the linear extrapolation resulted in negative years for the shortest time periods, we adjusted to zero. This may indicate underconfidence in the responses provided by the experts, or that the use of linear extrapolation for these 4-point elicitation responses fails to distribute expert uncertainty in a manner consistent with the actual uncertainty present in expert responses (i.e., the experts could have been more confident in their shortest plausible time response than their longest plausible time responses, which the linear extrapolation doesn't account for).

[3] Expert confidence that the true recovery time would fall between the shortest and longest time periods of their response.
[4] This expert provided a response for two scenarios, first that the catastrophic event does not result in habitat loss, and second that habitat is lost and therefore connectivity to extant populations is lost.
[5] This expert provided separate responses for each geographic unit. The values in this table are the overall shortest, longest, and average most plausible number of years indicated in the responses across geographic units.

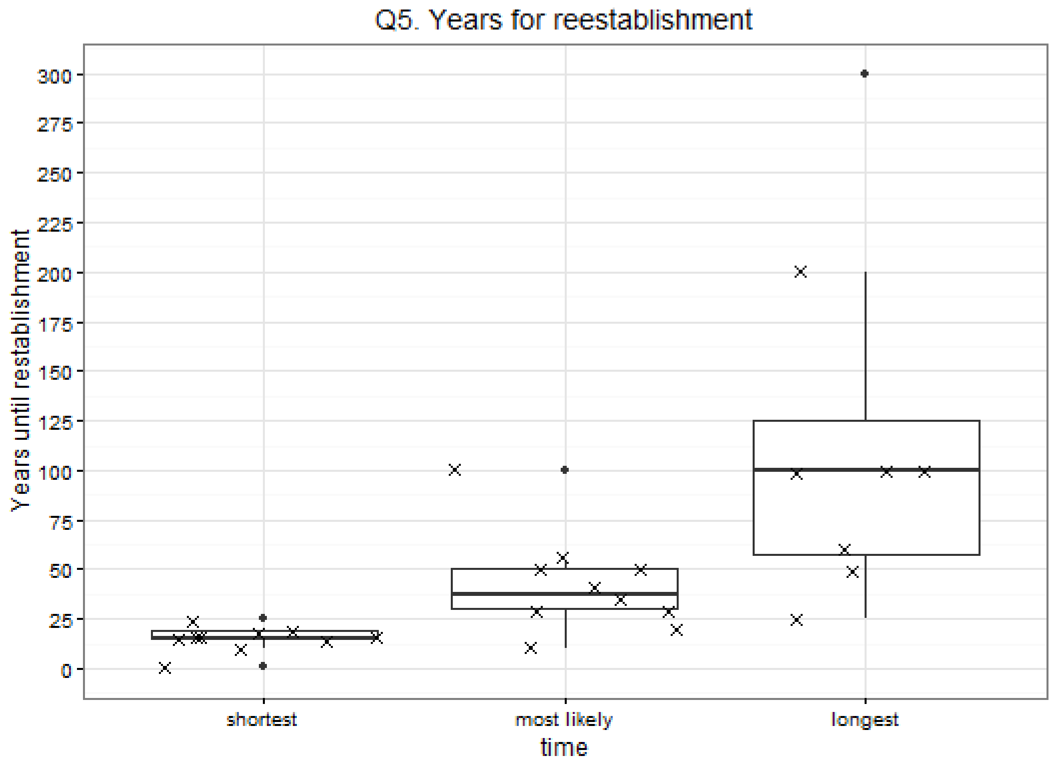

Figure 3. Years for a geographic unit to become reestablished following extirpation due to catastrophic events.

The raw responses for each of the three time periods (longest plausible time to reestablishment, most plausible time, and shortest plausible time period) are displayed in the box plots in Figure 3 above. Boxplots illustrate response mean values (bold black lines), the 25% and 75% quartiles (upper and lower bounds of boxes), and the highest and lowest values within 1.5 times the quartile range (“whiskers” external to boxes). In this analysis, responses beyond the ends of the whiskers are considered outliers and plotted as points. The individual expert responses used to produce the boxplots are indicated by x-marks. Boxplots are provided as a summarizing visualization to aid comprehension of the experts’ responses and their range, and the summary values are presented in this context and not intended for use outside of the context of the full set of responses.

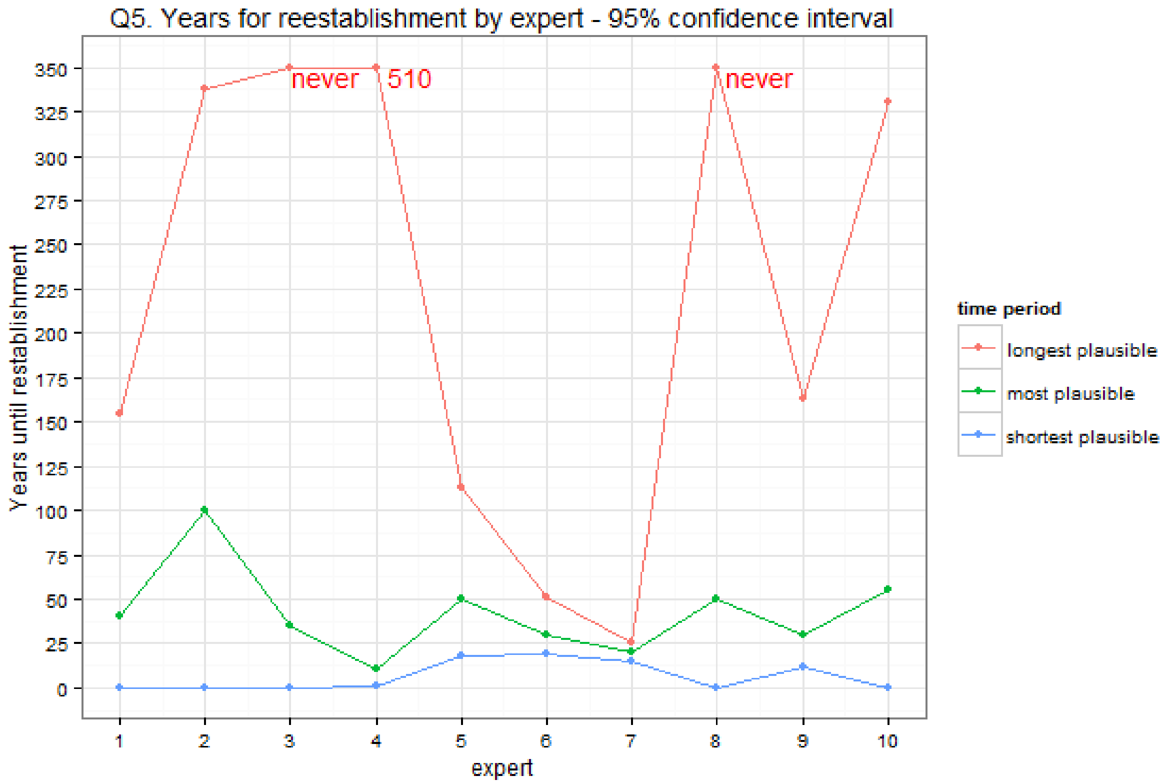

Figure 4. Years for a geographic unit to become reestablished following extirpation due to catastrophic events, adjusted to provide 95% confidence bounds.

In Figure 4, 95% confidence bounds were produced from the 4-point responses using linear extrapolation. Shortest plausible time period is in blue, most plausible is green, and longest plausible is red. For plotting purposes negative shortest time period values were adjusted to zero, and all zeroes in the plot indicate 95% confidence bounds that extended below zero. Longest time periods beyond 350 years were plotted at 350, with the actual time period noted in text left and below those points. Also note that expert 10 responded by geographic unit, so the figure displays the 95% confidence bound adjusted overall longest, overall shortest, and average most plausible time periods across the six units for expert 10.

Discussion Points Following Initial Responses: Experts discussed the amount of time it takes for habitat to recover after catastrophic events (e.g., fire, insects) when considering timeframes for repopulation. Some experts could picture some geographic units never being recolonized again, and that some could be recolonized immediately, depending on which geographic unit is being evaluated and the level of connectivity to other geographic units and to lynx populations in Canada. Washington is more connected to Canada than the Colorado geographic unit for example. The rate of recolonization was variable for each geographic unit because of the size of each geographic unit, status of adjacent source geographic units, and the level of connectivity. Experts found it hard to generalize across the range of the species for this question. The variances in the geographic units across the range need to be considered. Experts believed GYA and CO would have a long period for recolonization, if ever recolonized, after a potential extirpation event because of the lack of connectivity with Canadian populations. It is likely that those geographic units with connectivity to Canada would recover much sooner than geographic units not connected to Canada.

Resiliency

Definition - ***Resiliency*** speaks to an individual population's ability to tolerate environmental and demographic stochasticity, such as fluctuations in temperature or genetic drift. It is often measured in terms of population size and growth rate, but in fact is dependent on a number of traits, both demographic and environmental. These include, among others: age or stage class distribution, genetic heterogeneity, birth rates, annual survivorship, sex ratios, etc., and the quality and extent of habitat, the degree of disease, competition, etc. Metapopulation dynamics and distribution can also contribute to population resiliency in some species.

Resiliency Questions: Probability of Persistence Exercise

Exercise Summary

The first two resiliency questions were asked concurrently as part of a probability-of-persistence exercise conducted for each geographic unit. Experts were asked to graphically provide the probability of persistence of resident lynx through time for each geographic unit, as well as the major factors influencing persistence in those geographic units, one geographic unit at a time. Experts were asked to provide persistence probabilities and influencing factors for the near-term (2025), mid-term (2050) and longer-term (2100). Experts were also asked to indicate on each of their graph sheets the emissions scenario (low, moderate, or high/status quo) they were considering in graphing persistence probabilities and listing influencing factors.

We began this exercise with the Northern Maine geographic unit, and the discussion and questions among experts that followed the initial persistence-graphing and factor-listing efforts indicated that a review of the status and major issues confronting lynx in each unit (a quick reminder and summary of the earlier status update presentations) would be helpful. Therefore, prior to expert responses for the remaining units, the expert(s) most familiar with the geographic unit in question gave a 5-10 minute summary of what they viewed as the most relevant information about the current and likely future status of lynx populations and habitats in that unit. They also presented any other conditions or issues they thought could affect the probability of persistence of resident lynx in that unit. All experts then completed their graphs and lists of the factors that influenced the probabilities of persistence they selected for each time frame for the geographic unit in question. For the Maine unit, the discussion following initial responses served the same purpose, and after that discussion, experts were given the opportunity to revise their responses if they felt it necessary.

After all experts completed their responses, the graphs and influence lists from each expert were posted on the wall, and workshop participants were invited to gather around to view and discuss the range of responses. Facilitators and SSA Team members then polled the experts about what drove their responses. These questions were a mix of directed questions about unique responses, the role of particular factors noted in the responses, and open-ended questions to allow experts to describe their thinking. Experts and team members were also encouraged to ask clarifying questions about the responses. Experts were encouraged to modify their responses by posting a revised sheet above their first response if they wished to adjust their responses based on the discussions.

1. What is the probability of persistence over time (particularly at present, 2025, 2050, and 2100) for each of the 6 major geographic units?

Response Type: Graphical 3-point elicitation. Each expert was provided a blank sheet of graphing paper with a y axis of probability of persistence, and an x axis of time, with 4 time periods bolded (2015, 2025, 2050, and 2100). For each of those years, experts were asked to add a point to the graph representing the lowest, highest, and most likely probabilities of persistence at that time period. Experts were also asked to connect the points through time.

Question Clarification: It was explained that the most likely point should represent the probability of persistence that the expert anticipates to be most likely to occur for that geographic unit at each time period, and that the points for lowest and highest probability of persistence were intended to capture the expert's uncertainty in the future probability of persistence. Experts preferred to indicate a most likely probability and to provide a full confidence interval (i.e., upper and lower bounds within which they felt 100% certain the future probability of persistence would fall) rather than indicate a confidence level associated with the lowest and highest probability responses.

Expert Responses: Responses are by geographic unit and are presented below in conjunction with the responses to question #2 below.

2. What are the major drivers/factors (up to 3) reducing probability of persistence for each of the major geographic units?

Response Type: Ranked list of top three factors, for each point in time (present, 2025, 2050, and 2100), with % contribution of each factor.

Question Clarification: Resiliency questions 1 and 2 were asked concurrently. Experts were provided a sheet of paper for each geographic unit and the area at the bottom of the sheet below the graphing area was used to list the three major factors they expected would most significantly influence the probability of persistence at each time period. Influencing factors were described as those anthropogenic or naturally-occurring activities, events or factors that could influence the probability that resident lynx populations will persist in a given geographic unit.

Expert Responses: For each geographic unit, an overview of the unit from the area expert are provided, as well a summary of the hand drawn graphs via a figure (Figures 5 - 10), the responses and major factors are summarized via text, and the discussion that the responses generated are presented.

Results by Geographic Unit

Northern Maine

Pre-graphing Overview from Unit Experts: This step was not added to the process until after the probability of persistence exercise for this unit. Because this unit was the first for which experts attempted to graph persistence over time, there were many questions and much discussion about process and intent. It was the discussion following this initial graphing exercise that led the SSA Team to request unit summaries prior to subsequent graphing exercises. The Team felt that overview information similar to that provided prior to graphing persistence for subsequent units (below) came out during the discussion. Further, because experts were encouraged to update their Northern Maine geographic unit responses as necessary following that discussion, the Team felt that the results of the graphing exercise for the Northern Maine geographic unit were valid and comparable to the results generated for the other units.

Expert Responses: All experts indicated an initially high and subsequently declining probability of persistence of resident lynx in Maine through the end of the century, with uncertainty (range between lowest and highest probabilities) also increasing over time. Nearly all experts predicted near-term (year 2025) persistence probability >= 90% and mid-century persistence >= 70%. All experts predicted end-of-century persistence probability >= 50% for this unit, with most predicting a 40% to 60% probability of persistence by 2100 (Figure 5). Near-term drivers that influenced experts' probabilities of persistence for this geographic unit were changes in private forest land ownership, changes in forestry management (timber harvest methods, volumes, and spatial distributions), habitat decline (succession of previous clear-cuts from young, dense regenerating stands to mature stands less conducive to high hare densities), spruce budworm outbreak, climate change-induced loss of spruce-fir habitats, and competition with bobcats due to climate change-induced loss of snow conditions that favor lynx. Longer-term (2050, 2100) drivers similarly included changes in forestry practices, but also climate-driven loss of snow conditions favorable to lynx/competition with bobcats, and loss of spruce-fir forest. As with responses for other geographic units, not all experts provided the factors that influenced their persistence probabilities for each time period, and not all provided the percent contribution of each factor.

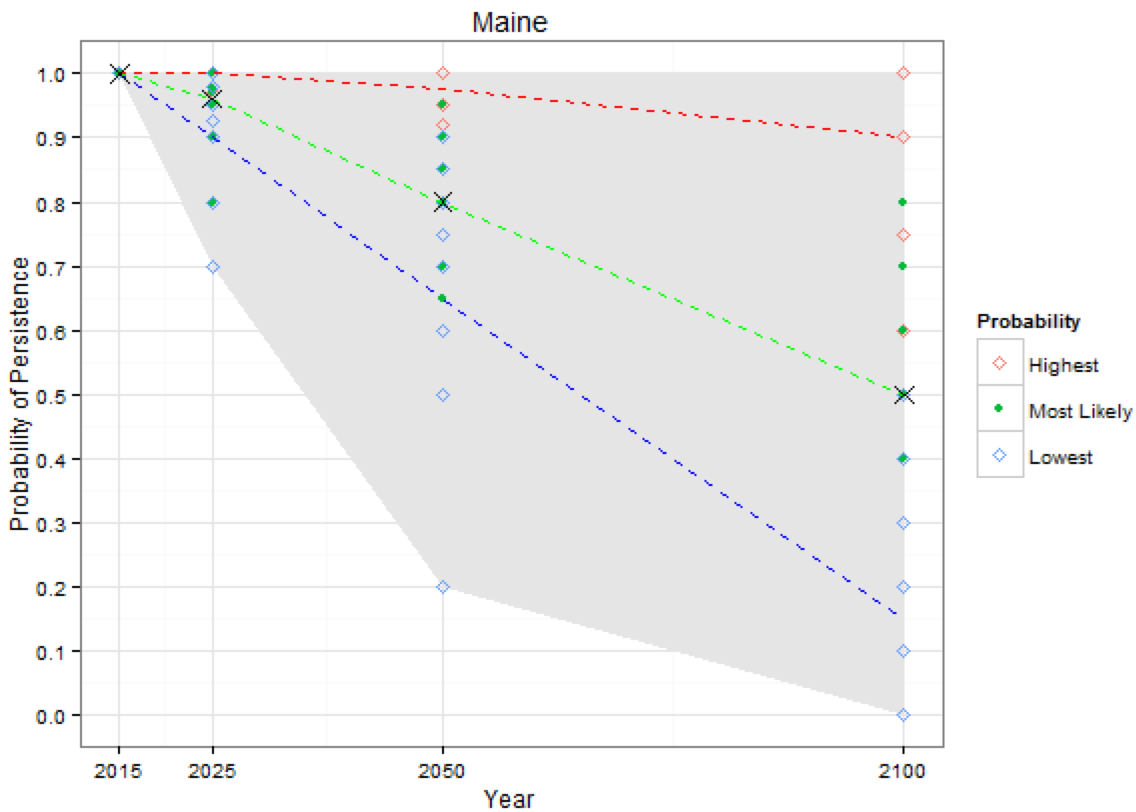

Figure 5. Expected probability of persistence for the Northern Maine geographic unit at present, 2015, and in 2025, 2050 and 2100.

Note: In Figure 5, above, and figures 6 through 10, below, points for each of the 10 expert responses, for each of the three probability of persistence levels, i.e., highest, most likely, and lowest probabilities of persistence, 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 grey area were defined by the extreme responses, i.e., the range from the largest of the highest probability of persistence responses to the smallest of the lowest probability of persistence responses. The median lines and grey area 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.

Discussion Points Following Initial Responses: One expert expressed confidence that the lynx population in Maine will be stable in the near term; that climate change out to 2050 will primarily affect coastal areas, which support few lynx; and that there will likely still be favorable conditions for lynx in northern Maine where most lynx currently occur. A second expert disagreed, and indicated that a combination of aging of the last of the budworm-era (1970s-80s) clear-cuts, the cumulative effects of the last 25-years of partial harvesting (in accordance with the Maine Forest Practices Act), and the coming spruce budworm outbreak will all substantially reduce the amount of high quality lynx/hare habitat in this unit. Projecting past 2050, experts generally agreed that climate change will likely create unfavorable conditions (e.g., insufficient snow, loss [northward migration] of spruce-fir forests) in northern Maine's core area for lynx, and the probability of persistence will decline over the longer term. Although uncertainty increases with time from the present, climate-related loss of favorable snow conditions (amount, consistency, and duration), loss of spruce-fir, and bobcat competition will likely reduce the probability of persistence in this unit beyond 2050.

There was some concern that timber companies would not respond to the pending spruce budworm outbreak like they did in the 1970s (extensive clear-cuts). Some experts also expressed concerns about the effects of the current clear-cuts aging past conditions that support hares and lynx. Out to year 2050, changes in snow conditions and loss of spruce-fir associated with climate change will contribute to habitat loss. Past 2050, diminished snow, successional loss of high-quality habitats, increased competition from bobcats, and spruce-fir decline will make conditions unfavorable for lynx. Some experts assumed a high-emissions climate change scenario, but others said their predictions would not change under moderate emissions scenarios. The second expert (above) indicated that current data show spruce-fir habitat is being replaced with a hardwood forest (red maple) system, and that this will continue throughout the century. This expert indicated hardwood forest invasion isn't being controlled by herbicides as it was in the last budworm outbreak. The first expert (above) disagreed and said that lynx are resilient and forestry practices will likely sustain spruce-fir habitats in Maine, providing an example of one timber company that has already invested in spruce plantations. The second expert indicated that most of the land base is owned now by Timber Investment Management Organizations and Real Estate Investment Trusts who will not employ intensive or expensive (plantation, herbicide) forms of forestry. In summary, experts expressed a variety of opinions about how forest management may change in the future in Maine and, in particular, how forest landowners and managers may respond to the pending spruce budworm outbreak, and how these responses may impact resident lynx.

Other factors considered by the experts included budworm outbreaks, the potential for disease in a lynx population (not currently a recognized or documented threat and typically unexpected, but always a possibility), ecosystem change induced by climate change, forest tree species composition changes, competition with other temperate forest animals. There are many interrelated factors and different stresses and factors that may occur in the future. It is difficult to anticipate the factors that will affect lynx in the future.

Experts discussed the role of competition between lynx and other carnivores, especially bobcats, throughout the DPS. One expert remarked that in some parts of Montana there is complete overlap of lynx and bobcat home ranges and little or no evidence of competition effects. Others indicated relatively narrow regions of overlap and sharp demarcation between areas that support home ranges of the two species that correspond with annual snowfall amounts in Maine and Minnesota. Experts were unsure whether bobcat-lynx overlap is more a function of snow conditions in these areas or competition between the species (i.e., competition for food or behavioral competition). Although separation of the species has been documented, the nature and causes of the separation are not certain. Bobcats are a more generalist predator than lynx and less reliant upon hares than lynx. Experts expressed varying opinions regarding seasonal differences in overlap among lynx and bobcat diets, the effect and importance of competition between the two species, and whether it is behavioral or resource competition.

Lynx in Maine have not responded to changes in hare abundance exactly as lynx in Canada and Alaska have to hare population cycles. In Maine, the proportion of females that reproduced and average litter size declined during low hare years, as in the north, but home range sizes in Maine did not increase as they did in the north when hare abundance was low. Hare densities do not appear to have dropped below a critical threshold to alter lynx home range size in Maine as in the North.

An SSA Team member asked how hare cycles or fluctuations may affect predictions of persistence in Maine. The first expert (above) said that hare declines documented by University of Maine monitoring is likely due to the aging forest, and that lynx in Maine haven't yet responded biologically to the range of hare densities observed in Maine, as suggested by the lack of change in home range sizes and survival. The second expert (above) disagreed, and cited University of Maine research that showed hare populations declined by ~50% in all stand types sampled starting in 2006, that forests where hares were monitored have not yet progressed to the self-thinning stage, and that the hare decline in Maine is mirrored by hare data from southern Quebec.

Northeastern Minnesota

Pre-graphing Overview from Unit Experts: There are probably 50-200 resident lynx in Minnesota but there is much uncertainty and survey protocols do not support generation of precise abundance estimates. Lynx occupancy and reproduction both have been consistently documented in the state since it was listed in 2000. Lynx in this geographic unit are interacting with, and possibly depending on, southern Ontario populations. Although females exhibit high reproductive rates, radio-telemetry data suggest low recruitment of Minnesota-born kittens into the breeding population of this geographic unit. Bobcats are a potential future stressor as they are encroaching into lynx areas; fire is a threat in dry years (e.g., there have been 3 fires in last 15 years that have burned approximately 20% of lynx habitat). The forest management industry is tied to softwoods and continued management of softwood tree species is expected in the future.

Expert Responses: As with the previous unit, all expert graphs showed initially high and subsequently declining probability of lynx persistence in Minnesota over time, along with increasing uncertainty through the end of the century. Nearly all experts predicted near-term (year 2025) persistence probability >= 90%, and all experts predicted mid-century persistence at 60% to 90% (median = 80%). Experts predicted end-of-century persistence probabilities of 10% to 60%, with a median of 35%, by 2100 (Figure 6). Near term drivers were reduced snow, bobcat competition, disease in lynx (e.g., lungworm, liver fluke, feline leukemia), and forest insects. Long term drivers were reduced snow, competition with bobcat, loss of spruce-fir forests, fires, and climate change.

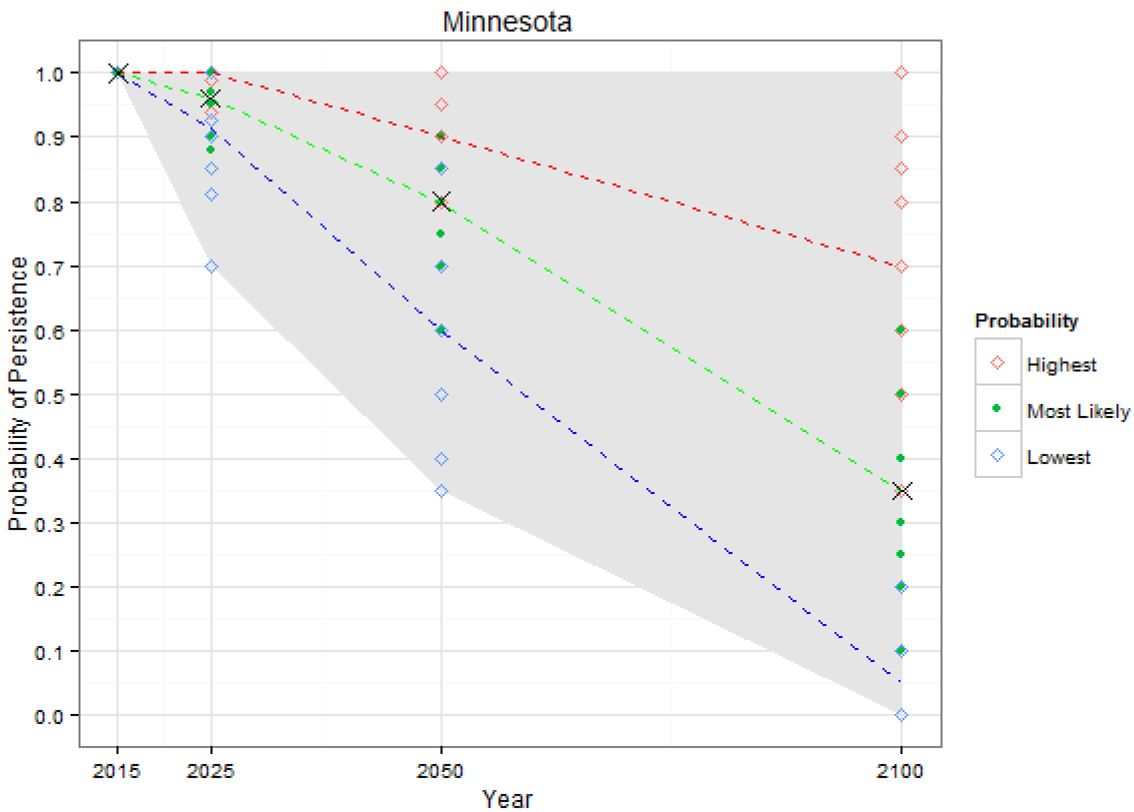

Figure 6. Expected probability of persistence for the Minnesota geographic unit at present (2015), and in 2025, 2050 and 2100.

Discussion Points Following Initial Responses: Some experts expressed uncertainty whether potential climate change impacts will be realized in the short term, but that the cumulative effects of climate-induced changes seem more likely in the longer term. This uncertainty may be a source of variability in predicted persistence probabilities.   Some experts expressed uncertainty about the accuracy of the rough estimate of the size of the lynx population in this unit because surveys were not designed to provide population estimates. Some experts wanted clarification on the distribution of lynx in the state, and which areas of the state have the highest use. The core-use spatial extent was described as a 20-mile-wide strip inland from the north shore of Lake Superior and extending about 60 miles from the northeast tip of the “arrowhead” southwest into the Superior National Forest (SNF). Lynx occasionally occur further west in the SNF and in other areas such as Voyageurs National Park. Recent snow-track surveys suggest lynx may be using a larger portion of the arrowhead region, and radio-telemetry data have documented travel to and from southern Ontario. Lynx also have been documented to use the

1-million-acre Boundary Waters Canoe Area Wilderness (BWCAW) that borders Canada for dispersal in both directions across the border. However, because the BWCAW has not been surveyed for lynx, the number of lynx that may use this area is unknown. The SNF does not actively manage the BWCAW. The current connectivity between lynx in this unit and the larger population in Ontario reduces the likelihood of local extirpation in this geographic unit, but the likelihood would increase if connectivity was compromised and cross-border interactions reduced.

Factors considered included potential disease, fire, loss of boreal forest, competition with bobcats and possibly other hare predators. Some experts questioned the validity of disease as an influence in this and other geographic units because although disease has been documented in some felines, it has not been documented as a threat to lynx in any of the DPS populations to date. Some experts speculated that because there is a link between disease and temperature increases in other animals, projected climate warming could contribute to disease in lynx. Therefore, although not a factor for lynx currently, it is not unreasonable that disease could impact lynx populations in the DPS in the future, so we may want to consider disease in future conservation planning. Experts also discussed the possibility that climate warming may facilitate the westward expansion of the spruce budworm outbreak that is projected for Maine and eastern Canada into southern Ontario and the Minnesota geographic unit.

Northwestern Montana/ Northeastern Idaho

Pre-graphing Overview from Unit Experts: There are likely 200-300 lynx in this unit in several subpopulations (expert stressed that this is a guess and not a true population estimate), and there is currently a connection with lynx in Canada. Climate models project that some boreal forest will persist in this unit and that it will maintain snow into the future. In this unit, lynx primarily occupy public lands, which are actively managed for lynx into the future. In recent decades, fires have occurred on a large scale, with high intensity and increasing frequency. There have been no documented cases of beetle infestations in lynx habitats in this unit.

Expert Responses: As for previous units, all expert graphs showed an initially high and subsequently decreasing probability of persistence for this unit, with increasing uncertainty over time, but a higher probability of persistence at all time frames than other units. All experts predicted near-term (year 2025) persistence probability >= 95%, and all predicted mid-century persistence at 70% to 100% (median = 90%). All experts predicted end-of-century persistence probabilities >= 50%, with a median of 78%, by 2100 (Figure 7).

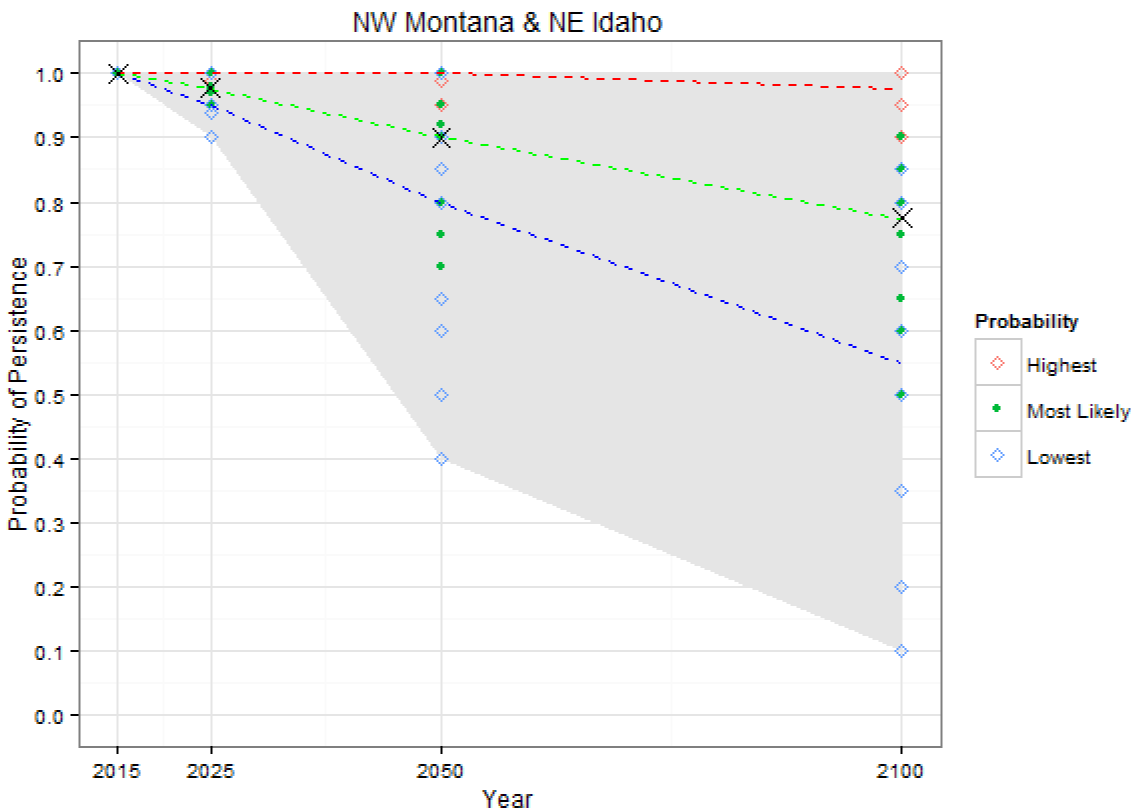

Figure 7. Expected probability of persistence for the Northwestern Montana/Northeastern Idaho geographic unit at present, 2015, and in 2025, 2050 and 2100.

Discussion Points Following Initial Responses: Overall, experts assigned a higher probability of persistence in this unit compared to the other two units discussed thus far. Most lynx habitats in this unit occur on Federal lands that are managed for lynx conservation, but one 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 due to 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 historic 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 three subpopulations (Purcell Mountains, Seeley Lake, and Garnet Mountains) in this unit. Experts noted that the Garnets Mountains subpopulation at the southern end of this unit may have recently become extirpated.

Discussion among experts indicated that fire was more of a concern for this area. 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 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 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 reminded 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 future.

North-central Washington

Pre-graphing Overview from Unit Expert: This geographic unit is thought to currently support roughly 50 resident lynx. There may have been more lynx prior to recent major fires. This unit is currently connected to Canada, and there is no indication that this connection will be disrupted. Some of the best lynx habitat in this 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, lynx and hares could migrate in response to warming. In areas that receive maritime climate influences, projected climate-induced changes to snow conditions could be detrimental for lynx. Studies have shown good lynx survival rates in this unit.

Expert Responses: Compared to the previous units, most expert graphs showed a lower probability of persistence for this unit over the short term, and then lower probability of persistence along with increasing uncertainty by 2100, reflecting a more pessimistic outcome for this unit compared to previous units (Figure 8). Experts predicted near-term (year 2025) persistence probabilities of 60% to 90% (median = 80%), and mid-century persistence at 30% to

80% (median = 70%). All experts predicted end-of-century persistence probabilities less than 50%, with a median of 38%, by 2100 (Figure 8). However, one expert predicted an increase in persistence probability by mid-century as habitats impacted by recent large-scale fires regenerate into optimal hare-lynx habitat.

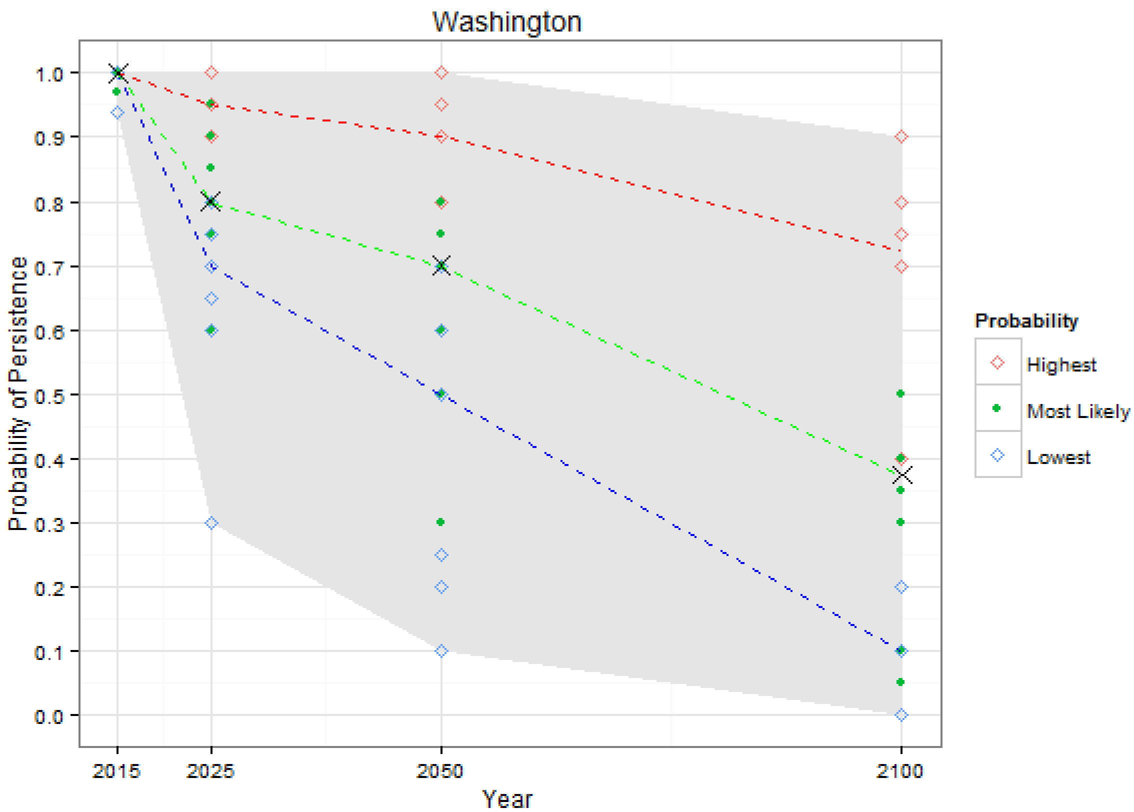

Figure 8. Expected probability of persistence for the North-central Washington geographic unit at present, 2015, and in 2025, 2050 and 2100.

Discussion Points Following Initial Responses: 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. 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. 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 none has 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 the Okanogan area of this unit could allow lynx to repopulate currently-unsuitable 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.

Greater Yellowstone Area (GYA)

Pre-graphing Overview from Unit Experts: This unit has a long history of lynx presence, but the consistency of occupancy over time is uncertain. Research and surveys since 1997 have detected few lynx in this unit. Lynx are likely spatially limited within the unit because of the patchy distribution of high-quality habitat and the generally low or marginal hare densities in much of the unit. Lynx have large home ranges in this area, an indicator of lower habitat quality. Nevertheless, until recently, this unit appears to have supported a small resident lynx population. The current lynx population in this unit is very small - likely fewer than 10 lynx, and possibly zero. This population may have been somewhat larger in the past; however, there is some uncertainty about this. Recent surveys and trapping efforts have not detected resident lynx, only several that were previously released in Colorado. Several Colorado-released lynx have established home ranges in the GYA unit, and there is evidence of overlapping male and female home ranges. In the late 1800s and early 1900s, there was notable predator control in some parts of this unit. There currently is oil and gas exploration and development activity in parts of this unit, but potential impacts to lynx are uncertain, and projects are attempting to minimize impacts to lynx habitat.

Expert Responses: The expert graphs for this unit were widely variable and had different outcomes and high uncertainty at all time frames. Experts predicted near-term (year 2025) persistence probabilities of 10% to 70% (median = 52%), and mid-century persistence at 15% to 60% (median = 35%). All experts predicted end-of-century persistence probabilities less than 50% for this unit, with a median of 15%, by 2100 (Figure 9). This was the only unit for which most experts believed the present probability of persistence is low (i.e., that it is uncertain whether this area currently supports a resident lynx population). Some experts increased probability of persistence into mid-century as the 1980s-era fires regenerate into hare/lynx habitat, and with the possibility of continued immigration of lynx from Colorado. Other experts project a 10% to 20% probability of persistence by 2100. One reason given for wide variability in responses is because of the uncertainty whether a population currently exists. There were wide confidence intervals around the probabilities for all time periods for this area.

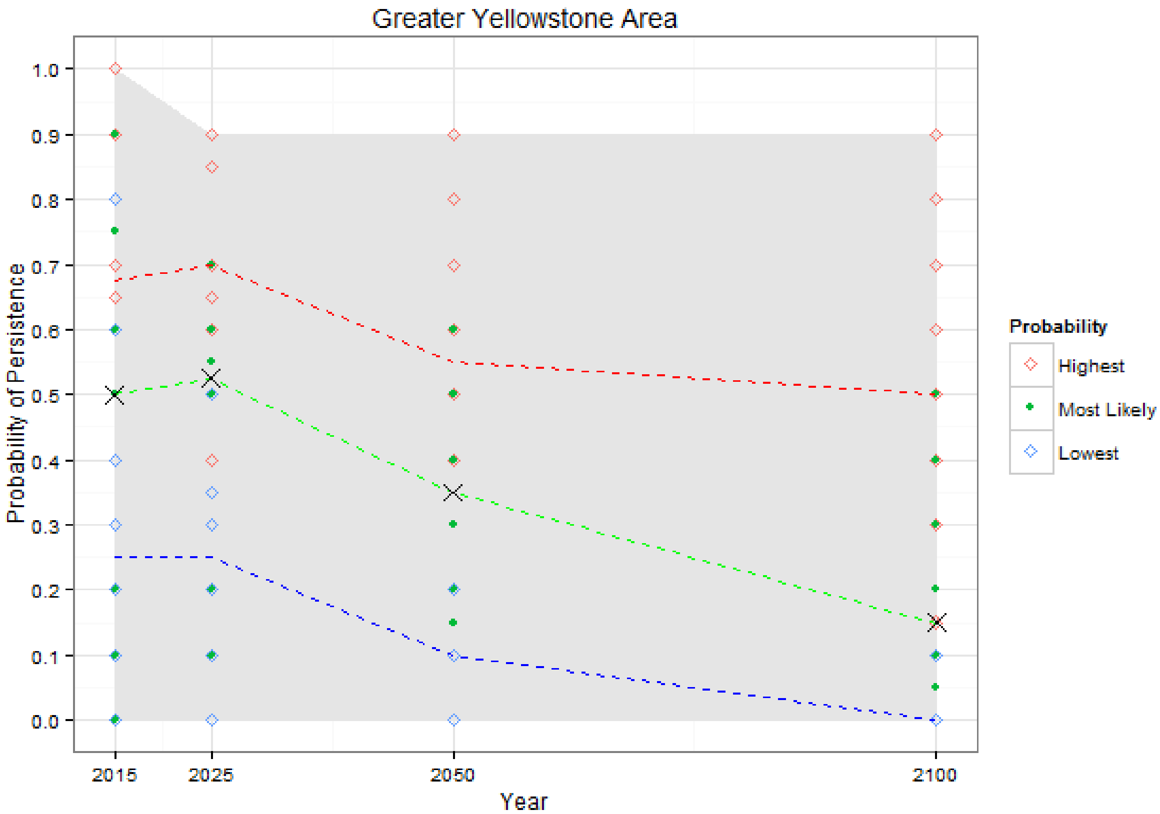

Figure 9. Expected probability of persistence for the GYA geographic unit at present, 2015, and in 2025, 2050 and 2100.

Discussion Points Following Initial Responses: 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. 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 refuge 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. Lynx immigrating 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 are maintaining or could maintain lynx in GYA.

Western Colorado

Pre-graphing Overview from Area Expert: From 1999 to 2006, Colorado Division of Wildlife (CDOW; now Colorado Parks and Wildlife [CPW]) released 218 Canadian and Alaskan lynx into western Colorado. Survival and litter sizes have been similar to rates observed in other DPS populations. There are probably 100-250 lynx in Colorado today. There are currently 5-6 million acres of habitat in this unit thought capable of supporting lynx and where hares are present in sufficient numbers to support persistent reproduction. Extensive bark beetle infestations have impacted large areas of lynx habitat, but snowshoe hare are still occupying areas with beetle damage. Three large fires have occurred in recent years, resulting in some lynx habitat burned. Salvage operations in burned areas could diminish future habitat quality. This unit is more isolated from Canadian and other DPS lynx populations; separated by a large swath of inhospitable habitat. Road mortality of released lynx was initially high but it doesn't seem to be a problem now (about 1 per year killed on roads on average since the first year of the reintroduction). There is no incidental take from trapping because foothold traps are banned in Colorado. Climate models show CO will maintain habitat over time with anticipated climate changes. Like other western units, habitat is patchily-distributed across this unit.

Expert Responses: Similar to most of the other units, most expert graphs indicate an initially high probability of persistence in this unit that will decline gradually with increasing uncertainty through the end of the century. Experts predicted near-term (year 2025) persistence probabilities of 60% to 100% (median = 90%), and mid-century persistence at 50% to 85% (median = 80%). Experts predicted end-of-century persistence probabilities of 20% to 70% for this unit, with a median of 50%, by 2100 (Figure 10).

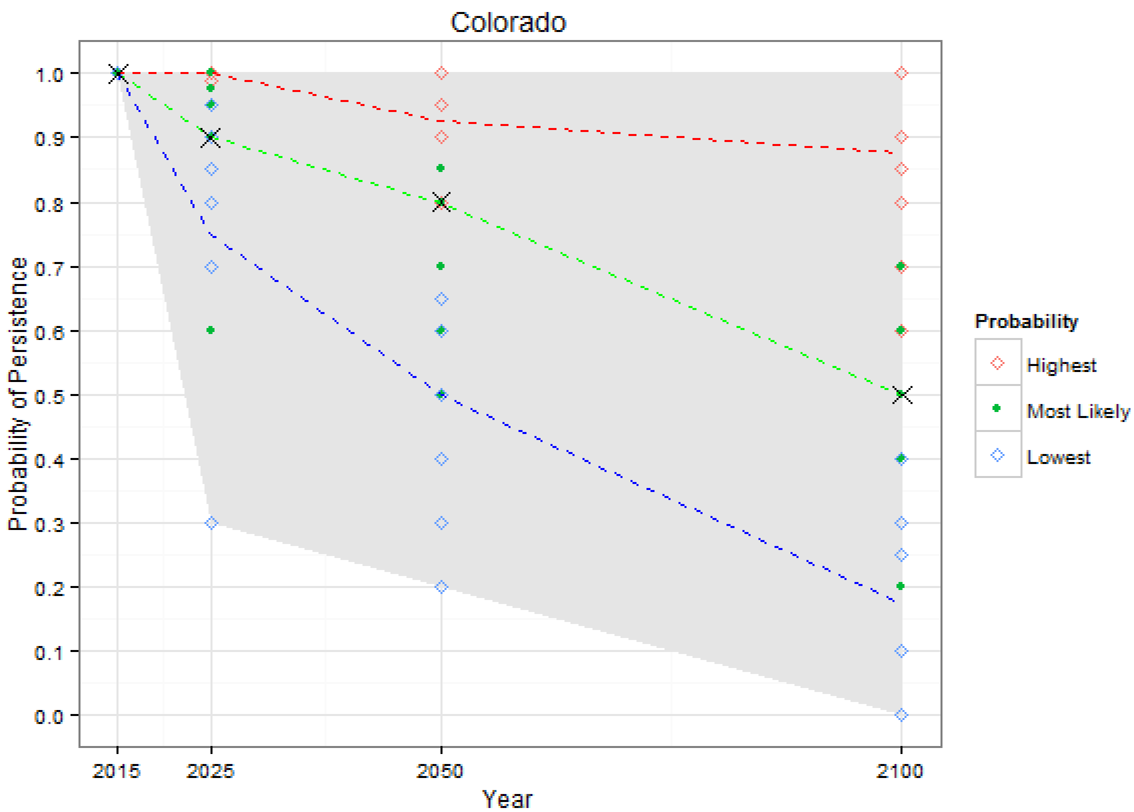

Figure 10. Expected probability of persistence for the Western Colorado geographic unit at present, 2015, and in 2025, 2050 and 2100.

Discussion Points Following Initial Responses: 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 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. Although 8 of 10 experts graphed 50% to 70% probability of persistence at 2100, during subsequent discussions, several expressed greater uncertainty about whether resident lynx will persist in the unit at the end of the century. Higher-quality lynx habitat occurs primarily in two 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 (similar to MT). 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 extirpated. There was discussion about whether ski areas may affect daily movements of lynx, and hares may be declining in ski areas. Ski areas tend to expand and may, therefore, have larger impacts on lynx in future. There is some evidence of lynx using ski areas in summer months but avoiding them during the ski season. It is uncertain whether ski areas may affect genetic connectivity within the Western Colorado geographic unit. Two-thirds to three-quarters of the lynx in this unit are in the southern portion of the range in the San Juan Mountains. There is a large area (Weminuche Wilderness) in Colorado that has not been well surveyed for lynx, so it is possible that lynx also could be using that area.

Summary across Geographic Units

This section extrapolates from the probability of persistence responses for each geographic unit in the section above. In this section we show the combined probabilities of persistence for those geographic units to provide a sense of what the DPS-wide results could be when the results for the individual geographic units are combined. This is shown as a summary of the probability that a given number of geographic units persist into the future (See Figure 11) using the probabilities provided for each individual unit. Note that no additional information was elicited to produce this summary; rather, the probabilities for each geographic unit were treated as independent probabilities of persistence and used to determine the joint probability of persistence for a given number of geographic units in total. Computationally these joint probabilities were computed using a convolution of the Bernoulli probability distribution of persistence for each geographic unit via a custom convolve function executed in the statistical software R (see Appendix 6 for the R code used to produce these and the other summaries and figures presented in the report). The results of this convolution are shown in two forms, first is the probability that a particular number of geographic units persists (Figure 11) and the second is the cumulative probability that at least a given number of geographic units persist (Figure 12).

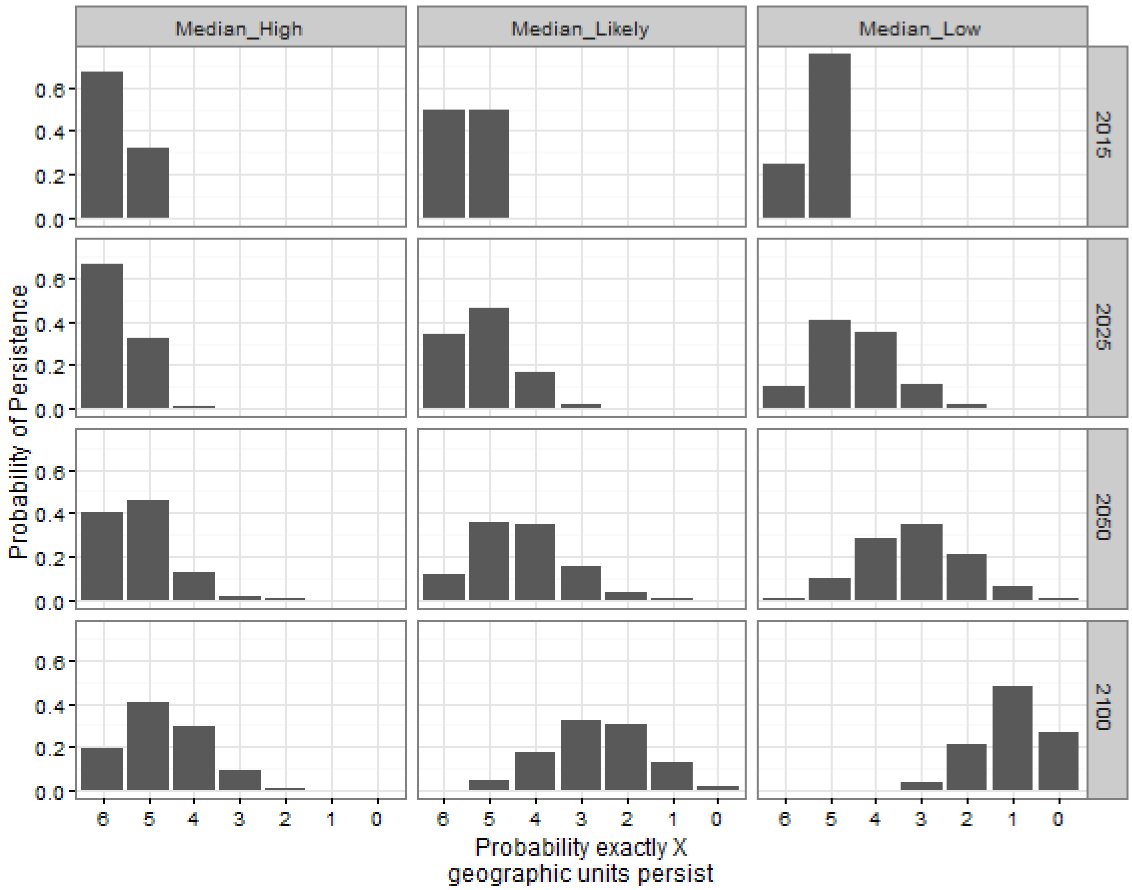

Figure 11. Summarized probability of persistence of a given number of geographic units given the probability of persistence for each individual geographic unit.

The y axis of each grid in Figure 11 is the probability that the specific number of geographic units indicated by the x axis of the grid persist. The probability sums to one in each grid. Moving from top to bottom the grids show the probabilities of a specific number of geographic units persisting by time period (2015, 2025, 2050, and 2100). Moving from left to right the grids show the range of expert responses by selection type and probability response.[6] 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 persistence experts had for a given time period. The summarized probabilities presented here are provided to aid understanding of the implications of the individual persistence probabilities provided above, and

[6] "Median_High" is the probability of persistence generated by selecting the ***median*** probability of persistence across experts from the ***highest*** probability response in each geographic unit. "Median_Likely" is the probability of persistence generated by selecting the ***median*** probability of persistence across experts from the ***most likely*** probability response in each geographic unit. "Median_Low" is the probability of persistence generated by selecting the ***median*** probability of persistence across experts from the ***lowest*** probability response in each geographic unit.

are derived directly from those responses and therefore should be presented and considered in conjunction with those figures.

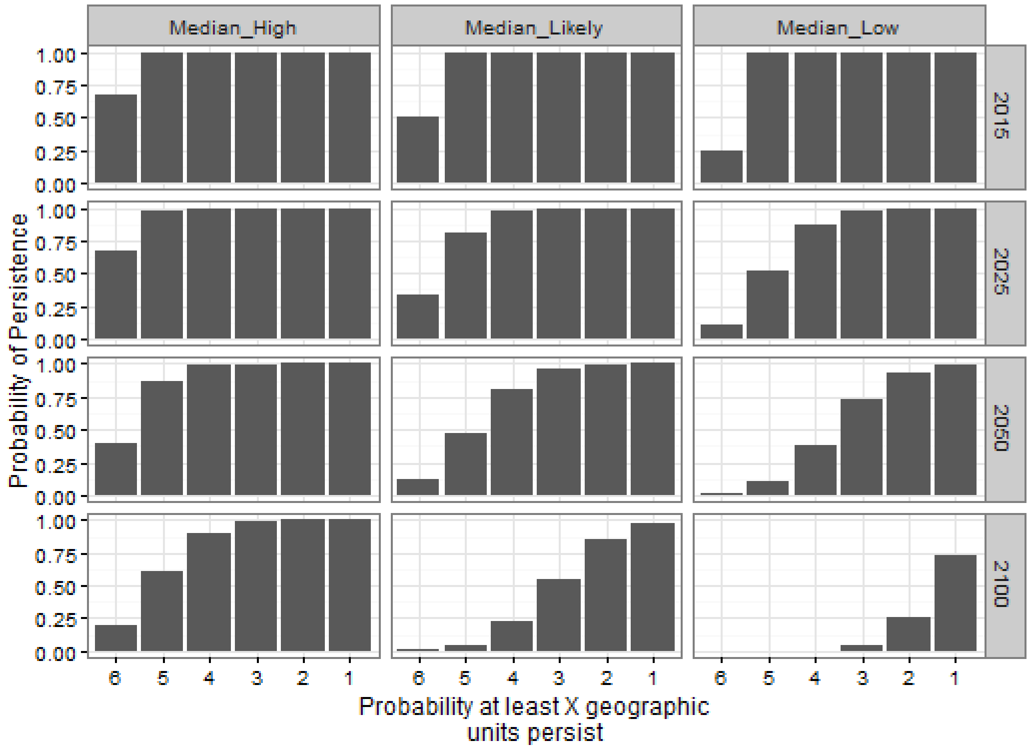

Figure 12. Summarized probability of persistence of at least a given number of geographic units given the probability of persistence for each individual geographic unit.

The y axis of each grid in Figure 12 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, 2025, 2050, and 2100). Moving from left to right the grids show the range of expert responses by summary selection type and probability response as in Figure 11. 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 persistence for a given time period. The summarized probabilities presented here are provided to aid understanding of the implications of the individual persistence probabilities provided above, and are derived directly from those responses and therefore should be presented and considered in conjunction with those figures.

Expert Assumptions during Persistence Graphing Exercises

Experts were asked to summarize the assumptions that informed their responses to resiliency questions 1 and 2. This was done via open discussion, with facilitators asking both direct questions about particular issues that could impact responses (e.g., climate change conditions), and open ended questions (e.g., what other assumptions were considered?).

Notes: Climate-change emissions scenarios considered during this exercise differed among experts (and some responses did not indicate an emissions scenario). However, in discussions following the graphing exercise, experts indicated that the confidence intervals around their persistence probabilities were likely to capture the variance associated with different emission scenarios and other climate change uncertainties.

Experts were asked whether regulatory protections influenced their predictions. Some experts assumed the status quo (i.e., continued protections under the ESA and current Federal and State land management policies). Others indicated their persistence probabilities were not influenced by regulatory considerations but that doing so would not have altered their projections. Their focus was on the biology and ecology of the species, not listing status-related impacts or regulatory scenarios in the future, and they felt that factors influencing lynx persistence on the landscape are independent of ESA listing status.

Experts were asked what they meant by "small population size effects." They explained that because small populations are more vulnerable to both demographic and genetic impacts and at increased risk from catastrophic and other stochastic events than are larger populations, they also have a lower likelihood of persistence. Experts indicated that connectivity with other populations reduces the vulnerability of small populations as it does for larger populations.

Experts were asked if their projections were influenced by considerations of whether historical patterns of cyclic irruptions of lynx into the DPS from Canada will continue in the future. Most agreed that the magnitude of irruptions has declined from the historical highs of the 1960s and 1970s, and that irruptions may have ceased in recent decades in some parts of the range, particularly in the West. However, most experts felt that connectivity remains good between Canada and those DPS geographic units that abut the international border, and most assumed some level of regular or intermittent interaction between lynx in those units and Canada, even if full-blown irruptions have not been documented recently. Some experts said that the likelihood of future irruptions had little influence on their persistence graphs, especially for the more isolated units (GYA and Western Colorado), where an influx of lynx from Canada may be less likely.

Conservation Actions to Address Influencing Factors and Increase Probability of Persistence

3. What conservation actions could be taken that would address the factors impacting the probability of persistence, or would otherwise increase the probability of persistence?

Response Type: Individual list with rounds responses. Experts were given 5 minutes to write a list of three potential conservation actions that could be taken. Facilitators then asked one expert at a time to provide one item from their list, cycling through the set of experts until all experts had exhausted their lists. Experts were given the opportunity to add items when it was their turn that had not been on their written lists. Experts were not asked if they agreed with conservation actions presented by other experts, thus the following list should not be viewed as consensus among lynx experts.

Expert Responses: List of potential conservation actions in the order provided.

- Reduce CO^2 emissions
- Continue protections associated with Federal and/or State listing
- Adjust forest management to retain spruce and fir, and reduce fire burn rates
- Promote/maintain habitat connectivity with Canadian populations through coordinated cross-border land use planning
- Manage salvage logging associated with fire and insect damage to minimize impacts to and/or facilitate restoration of lynx/hare habitats
- Configure and design lynx-friendly landscapes at appropriate scales; design and maintain a mosaic of lynx/hare habitats
- Manage fuels reduction (fire management) projects while maintaining or enhancing hare/lynx habitat features.
- Augment small populations and reintroduce lynx to former, historic range with suitable habitat (GYA, Kettle Range in Washington, perhaps other areas); bolster populations before future climate change impacts
- Support additional research to fill knowledge gaps, particularly related to effectiveness of conservation efforts – it remains unclear exactly what is needed for lynx across the range to achieve/maintain viability (e.g., habitat quality/amount/distribution, landscape-level hare densities, forest conditions that support hares, etc.)
- Enhance cross-border cooperation with Canada to increase near-border lynx populations and maintain connectivity
- Consider cumulative impacts of mining, ski areas, oil and gas, etc., in management
- Promote reforestation of heavily fragmented areas (e.g., some parts of the GYA and Minnesota units); reduce fragmentation
- Apply strategic habitat conservation concepts; model and identify key areas and focus on those areas still in need of protection and management (e.g., private forest lands)
- Maximize redundancy of lynx populations throughout the DPS
- Implement fire management Best Management Practices (BMPs)(e.g., allow/encourage burns to occur in a way that creates high- and low-intensity mosaic fire patterns)
- Evaluate whether there is a need for monitoring lynx (and hares) using consistent methods throughout the DPS, perhaps coupled with monitoring of other carnivores; structured occupancy modeling with genetics sampling could be very informative and is cost effective; also known-fate monitoring; monitoring pellet plots is proven and reliable way to monitor hares
- Devote increased funding to lynx conservation - lynx are in worse shape than other mesocarnivore species, but receive less funding than those species that have more secure populations and appear less vulnerable to climate change

Other Considerations

After completing the elicitation exercises and prior to adjourning the workshop, facilitators asked if there were any other considerations the lynx experts or subject matter experts felt are relevant to the SSA. One subject matter expert indicated that monitoring of prey base (hares, red squirrels) would help inform lynx recovery, and that pellet-based or mark-recapture methods are most reliable. This expert suggested a need to determine whether areas that we think are going to become poor habitat for a variety of reasons could still hold hares and lynx in the future. Maybe hares still can use areas we think will be poor habitat, and monitoring these areas could help inform our understanding of how lynx persist at the edge of their range.

Synthesis

Although uncertainty remains about the historical distribution and sizes of resident lynx populations in the DPS, as well as current population sizes, much more is known now than when the DPS was listed under the ESA in 2000. Based on research conducted since the DPS was listed, including the summaries of that work provided at this workshop, as well as ongoing research, conservation, and management efforts, we have a much better understanding of the distribution and status of populations throughout the DPS range. For example, in 2000, it was unclear whether Maine and Minnesota supported resident populations or were only occasionally visited by lynx dispersing from Canada during and after northern hare population crashes. We now know that both northern Maine and northeastern Minnesota support resident lynx populations, and both are likely larger now than they were historically (Maine), or before they were protected by State and Federal regulations (Minnesota). In contrast, resident lynx appear to be naturally less abundant and more patchily-distributed in some parts of the DPS than thought at the time of listing, including the West (Interagency Lynx Biology Team 2013, p. 23), where potential lynx habitats also appear to have been initially overestimated. We also have a better understanding of the habitat features and hare densities that appear necessary to support resident lynx at the southern margin of the species' range, and of the parts of the contiguous U.S. that contain these features. The presentations in conjunction with expert elicitation responses at this workshop have informed and refined our understanding of key aspects of the status of, and potential threats to, the lynx DPS.

For example, we were provided a thorough history of the evolution of regulatory mechanisms that have been developed and implemented through conservation agreements and formal amendments to Federal agency management plans to address the singular threat for which the DPS was listed under the ESA - the inadequacy of regulatory mechanisms in Federal land management plans prior to listing. Given our improved understanding of resident lynx populations in Maine and Minnesota (above), where State and private lands constitute much more of the lynx habitat than elsewhere in the DPS (98.9% in Maine; 51.7% in Minnesota), an assessment of the adequacy of regulatory mechanisms on those State and private lands will be a necessary component of the status assessment. Likewise, our understanding of lynx genetics also has improved, with evidence of continued high levels of gene flow range-wide, despite fine-scale genetic sub-structuring in some populations and additional evidence of lynx hybridization with bobcats. Bobcats appear to be encroaching at the edge of the lynx range in Minnesota (Appendix 3, p. 9) and their numbers appear to have increased recently in New Hampshire, Vermont, and southern Quebec (Lavoie *et al*. 2009, entire; Roberts and Crimmins 2010, p. 170; Broman *et al*. 2014, p. 230) adjacent to the northern Maine lynx distribution. Whether this represents a threat to lynx populations in Minnesota and Maine via increased hybridization, behavioral mechanisms, or competition for hares is not documented at this time; however, encroachment of bobcats in the southern periphery of lynx range may result in lynx displacement or niche contraction (Peers *et al*. 2013, entire).

Canadian researchers also provided updated information on lynx status, management (including legal harvest), threats, genetics, and hare population cycles in southern Canada, adjacent to some DPS lynx populations. Forest ecologists and climate modelers also presented information regarding potential impacts of timber management and climate change on lynx and boreal forest habitats in the contiguous U.S. Knowledge of lynx and hare responses to various silvicultural treatments continues to improve, although the need for continuing research remains. Climate models continue to point toward the future northward and upslope migration of lynx and hare habitats and loss of snow conditions favorable to lynx, although uncertainty remains regarding the timing, extent, and biological consequences of such impacts. Increases in the size, intensity, and frequency of wildfires and insect outbreaks in boreal/subalpine forests may also be related to climate change, but whether these represent temporary or permanent impacts to lynx habitats remains unclear. Finally, much research has been done on hare population dynamics and habitat relationships at the southern extent of their range, much of which overlaps that of lynx in the contiguous U.S., but questions remain regarding regional variation in hare densities and what landscape-level hare abundances are necessary to support persistent resident lynx populations across the DPS.

Based on the summaries of post-listing research and the status and threat updates provided at this workshop, and on the results of the expert elicitation process, the Service provides the following synthesis of the status and likely viability of the DPS in terms of the 3 Rs. This information will be considered as appropriate, along with more detailed analysis of the published literature, in the subsequent SSA report for the DPS. The conclusions below are based on the information provided and the results of expert elicitation conducted at this workshop; they may be complemented or altered by the additional analyses yet to be conducted as part of the SSA process.

Representation

Expert presentations on lynx genetics in the DPS and in Canada and expert responses and discussion with regard to representation questions suggest few threats to the genetic fitness or adaptive capacity of lynx in the DPS. High gene flow across the continental lynx range, indicated by very low F_{st} values (see *Subject Matter Presentations*, above), suggests the absence of substantial barriers to genetic interchange, and little evidence or risk of significant genetic drift among DPS populations. Most experts indicated that none of the six geographic units known or thought to support lynx populations in the DPS is susceptible to meaningful genetic drift, although several experts indicated that the more geographically isolated units (the GYA and Western Colorado units) are likely more susceptible to such drift than the units that are directly connected to lynx populations and habitats in Canada. Overall, according to both the expert panel and the subject matter presentations, there appears to be a low risk of biologically consequential drift for lynx populations in the DPS. Likewise, expert responses indicated that the generally low level of genetic differentiation and relatively similar ecological settings across the DPS suggest little life history variability or niche differentiation among DPS populations that would indicate that any are more or less important to maintain than others in terms of representation. Individual experts indicated that representation can best be maintained by conserving current DPS populations (and hence the genetic variation in each), maintaining connectivity between DPS and Canadian populations, and avoiding impacts that would facilitate or increase the potential for or likelihood of genetic drift. Our interpretation of this part of the elicitation is that the adaptability and evolutionary capacity of the DPS over time does not appear to have been diminished and is unlikely to become so, independent of threats that may impact the redundancy and persistence of lynx populations. We will consider this information along with available empirical data and the published literature when evaluating representation in the DPS for the SSA.

Redundancy

With resident lynx populations and subpopulations in at least five of six large (the smallest is over 2,000 square miles, the others are all over 8,000 square miles), widely-distributed (from Maine to Washington and south along the Rocky Mountains), and relatively discrete geographic areas (see Figure 1), the DPS as a whole appears invulnerable to extirpation from a single catastrophic event. Expert responses indicated no catastrophic event that could result in the functional extirpation of the entire DPS and, further, no or a very low likelihood of functional extirpation of any of the individual geographic units due to a single catastrophic event. We interpreted these responses to indicate there is a small chance of decreased redundancy from a single catastrophic event because the probability of any geographic unit being lost to a catastrophic event is low. Experts indicated that functional extirpation of the geographically smallest unit (Washington) and those supporting the fewest resident lynx (Washington, GYA, and perhaps Minnesota) would be more likely to occur as a result of a series of catastrophic events over a 10-year period than to any single event over the next 10 years (see Figure 2 above). Experts listed fire, drought, insect outbreaks, loss of favorable winter conditions, and disease as potential events that could lead to functional extirpation in these units. In Washington in particular, where large fires have impacted nearly 40 percent of the occupied lynx habitat over the past 10-15 years, experts felt that several more successive years of such fires could result in functional extirpation. However, because fire and insects are likely to cause only temporary (20-40 years) losses of lynx and hare habitats, and because connectivity between the Washington unit and lynx habitats and populations in southern British Columbia remains intact, experts indicated this unit (and others abutting habitats and lynx populations in Canada) would likely be naturally re-colonized relatively quickly by dispersing lynx. Therefore, extirpation in these units because of catastrophic events (or a series of them over time) would be temporary (likely lasting only one or several decades) unless events permanently altered the habitats. Experts indicated that if lynx were functionally extirpated in the GYA or western Colorado units, which are not connected to habitats or populations in Canada and are relatively isolated from other DPS populations, natural re-colonization would be less likely, would take longer, or may never occur.

Overall, expert responses indicated that extirpation of the DPS as a whole, or of resident lynx populations in most individual geographic units, because of a catastrophic event is very unlikely. Because we lack evidence that persistent resident lynx populations occurred historically but have been lost from any other large geographic areas in the contiguous U.S., 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 the historic record, was likely in areas (e.g., northern New Hampshire, Michigan's Upper Peninsula, the Kettle/Wedge area of northeastern Washington, perhaps Isle Royale in Lake Superior) peripheral to the geographic units that currently support resident lynx, and not in discrete geographic units that would have represented greater redundancy in the contiguous U.S. However, the implications of the potential recent loss of resident lynx in the GYA for the redundancy of the DPS are unclear. The historic record and recent research show that the GYA has supported resident lynx, but it is unclear whether the area consistently supported a persistent resident population over time or whether it naturally supported resident lynx only some of the time (was "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, its contribution to redundancy within the DPS is questionable.

Resiliency

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 resiliency of individual populations or the DPS as a whole. Efforts to understand resiliency are also confounded by the metapopulation structure thought to govern lynx populations at the southern margin of their continental range (i.e., populations and subpopulations in the DPS), 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 historic record that limits our understanding of the relative persistence of lynx in various geographical areas of the contiguous U.S. and, thus, the contribution of those areas to the viability of the DPS. Our evaluation of the resiliency of lynx populations in the DPS is limited, therefore, to a largely qualitative assessment of the current status of populations in each of the six geographic units along with the quantitative summary of expert professional judgment of their likelihood of persistence over time given known or perceived potential threats.

As expected, both expert estimates of probability of persistence and expert confidence in those estimates were higher over the short-term than the long-term. Median probability of persistence (MPOP) at year 2025 was >= 0.90 for all but one of the six geographic areas. The GYA had a MPOP of 0.52, apparently reflecting the uncertainty regarding whether this unit consistently supported a resident lynx population historically and whether it currently supports resident lynx. At year 2025, confidence bounds were smallest (indicating higher expert confidence) for the units with the highest MPOPs (Northern Maine, Northeastern Minnesota, and Northwestern Montana/ Northeastern Idaho), and larger for units with lower MPOPS (North-central Washington, GYA, and Western Colorado). At mid-century, MPOP declined for all units but remained >= 0.70 for all but the GYA (0.35), and confidence bounds increased for estimates for all units but the GYA, where it remained the same as at year 2025. At end-of-century, persistence probabilities declined further, as expected, and only the Northern Maine, Northwestern Montana/ Northeastern Idaho and Western Colorado units had MPOPs >= 0.50. Also as expected, confidence bounds were very large around persistence estimates at year 2100, with the median confidence range extending across more than 50% of the range of possible outcomes for all but the Northwestern Montana/ Northeastern Idaho population, and the extremes of the range nearly covering the full range (0% to 100% probability of persistence) of possible outcomes.

Experts listed a number of factors that influenced their probability of persistence estimates for each unit (see unit summaries above in the *Resiliency* section). Near-term factors varied by unit (e.g., post-harvest forest succession in Maine, where hare abundance is expected to decline as currently dense regenerating clear-cuts mature; continued large-scale fires in lynx habitats in Washington; and insect outbreaks in Maine, Minnesota, and Colorado), but longer term factors seemed to coalesce around anticipated direct and indirect effects of climate change. These included potentially climate-driven increases in the size, frequency, and intensity of fire and insect outbreaks; decreases in snow amount, duration and quality, leading perhaps to increased competition with bobcats and other hare predators; and the projected warming-induced northward and upslope migration of boreal and subalpine forests that would result in the loss and further fragmentation and isolation of lynx and hare habitats in the contiguous U.S. Expert responses and ensuing discussions indicated that continued climate warming and associated direct and indirect effects will likely exert the greatest negative influence on the probability of persistence for lynx populations in the DPS regardless of which climate emissions scenario is used to model future conditions, although the timing, extent, and magnitude of impacts is uncertain and will likely vary by scenario.

Overall, expert responses to this part of the elicitation indicate that all five of the geographic units known to currently support resident lynx populations have a greater than 70% expectation of doing so by mid-century, but a declining likelihood and greater uncertainty of doing so by the end of the century. It is uncertain whether the remaining geographic unit (the GYA) currently supports resident lynx, and expert responses indicate a lower probability that it will do so in the future compared to the other units. Responses also suggest that the overarching threat to the long-term persistence of lynx populations in the DPS is climate change, which is anticipated to result first in loss of snow conditions favorable for lynx and, after an uncertain lag time following continued climate warming, loss (northward and upslope migration) of boreal forest habitats, although the timing and magnitude of such losses are uncertain.

Conclusion

The Service and the Lynx SSA Team appreciate the willingness of lynx and subject matter experts to attend this workshop and share their knowledge, professional judgments, and opinions. We have gained considerable insight into the current status of lynx populations throughout the DPS and the factors most likely to influence the DPS's future viability - including information that is not currently available in the peer-reviewed literature. We will incorporate this information into the SSA as appropriate, along with the published scientific literature, to inform recovery planning for the DPS and any other ESA-related determinations the Service is authorized and required to make. As we develop the SSA report, we will continue to solicit expert input from workshop panelists and from other lynx and subject matter experts who were unable to attend this workshop, including peer review of the SSA report.

Literature Cited

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. http://www.gpo.gov/fdsys/pkg/FR-2006-11-09/pdf/06-9090.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. http://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. April 18, 2007. https://www.gpo.gov/fdsys/pkg/FR-2007-04-18/pdf/E7-7342.pdf#page=1

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. http://www.gpo.gov/fdsys/pkg/FR-2009-02-25/pdf/E9-3512.pdf#page=1

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. September 12, 2014. https://www.gpo.gov/fdsys/pkg/FR-2014-09-12/pdf/2014-21013.pdf

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.

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.

Broman, D. J. A., J. A. Litvaitis, M. Ellingwood, P. Tate, and G. C. Reed. 2014. Modeling bobcat Lynx rufus habitat associations using telemetry locations and citizen-scientist observations: are the results comparable? Wildlife Biology 20: 229-237.

Buehler, D. A. and L. B. Keith. 1982. Snowshoe hare distribution and habitat use in Wisconsin. Canadian Field-Naturalist 96: 19-29.

Burgman, M. 2005. Risks and decisions for conservation and environmental management. Cambridge University Press.

Buskirk, S. W., L. F. Ruggiero, and C. J. Krebs. 2000b. 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.

Drescher, M., A. H. Perera, C. J. Johnson, L. J. Buse, C. A. Drew, and M. A. Burgman. 2013. Toward rigorous use of expert knowledge in ecological research. Ecosphere 4:Article 83. (http://dx.doi.org/10.1890/ES12-00415.1)

Elton, C. and M. Nicholson. 1942. The ten-year cycle in numbers of the lynx in Canada. Journal of Animal Ecology 11: 215-244.

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.

Gregory, R., L. Failing, M. Harstone, G. Long, T. McDaniels, and D. Ohlson. 2012. Structured decision making: a practical guide to environmental management choices. John Wiley & Sons.

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

Koehler, G. M. 1990. Population and habitat characteristics of lynx and snowshoe hares in north central Washington. Canadian Journal of Zoology 68: 845-851.

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.

Kosterman, M. K. 2014. Correlates of Canada Lynx Reproductive Success in Northwestern Montana. M.S. Thesis, University of Montana, Missoula. 69 pp.

Lavoie, M., Collin, P-Y, Lemieux, F., Jolicoeur, H., Canac-Marquis, P., Lariviere, S. 2009. Understanding fluctuations in bobcat harvest at the northern limit of their Range. Journal of Wildlife Management 73: 870-875.

MacMillan, D.C. and K. Marshall. 2006. The Delphi process – an expert-based approach to ecological modelling in data-poor environments. Animal Conservation, 9: 11–19.

McBride, M. F., S. T. Garnett, J. K. Szabo, A. H. Burbidge, S. H. M. Butchart, L. Christidis, G. Dutson, H. A. Ford, R. H. Loyn, D. M. Watson, and M. A. Burgman. 2012. Structured elicitation of expert judgments for threatened species assessment: A case study on a continental scale using email. Methods in Ecology and Evolution 3: 906–920. doi: 10.1111/j.2041-210X.2012.00221.x http://onlinelibrary.wiley.com/doi/10.1111/j.2041-210X.2012.00221.x/full

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.

McKelvey, K. S., K. B. Aubry, and Y. K. Ortega. 2000. 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.

Moen, R., C. L. Burdett, and G. Niemi. 2008. Movement and habitat use of Canada lynx during denning in Minnesota. Journal of Wildlife Management 72: 1507-1513.

Morgan, in prep.

Morgan, M. G. 2014. Use (and abuse) of expert elicitation in support of decision making for public policy. Proceedings of the National Academy of Sciences 111(20):7176-7184.

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.

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. Proceedings of the Royal Society B 280: 1-10. http://dx.doi.org/10.1098/rspb.2013.2495

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; e1944-687X. doi: 10.3996/122009-JFWM-026

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., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires. 2000. 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.

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.

U.S. Environmental Protection Agency (USEPA). 2011. Expert elicitation task force white paper. Science and Technology Policy Council, USEPA, Washington DC. (http://www.epa.gov/stpc/pdfs/ee-white-paper-final.pdf)

U.S. Fish and Wildlife Service. 2005. Draft recovery outline for the contiguous United States distinct population segment of the Canada lynx. Unpublished draft. U.S. Fish and Wildlife Service, Region 6, Denver, Colorado. 21 pp.

Wolff, J. O. 1980. The role of habitat patchiness in the population dynamics of snowshoe hares. Ecological Monographs 50: 111-130.

Appendices

All appendices are available on the Service's Region 6 Canada lynx webpage (http://www.fws.gov/mountain-prairie/es/canadaLynx.php).