Mount Rainier White-tailed Ptarmigan (*Lagopus leucura rainierensis*)

Species Status Assessment

Version 1

Prepared by:

U.S. Fish and Wildlife Service, Department of Interior Region 9

Cover photo by Jamie Hanson, USFWS

ACKNOWLEDGMENTS

We would like to recognize and thank the following individuals, agencies and organizations who provided substantive information and insights for our SSA analyses.

A huge thank you to the British Columbia Breeding Bird Atlas for supplying data. We would also like to thank the following partners: Bird Studies Canada, Canadian Wildlife Service, British Columbia Ministry of Environment, BC Nature, BC Field Ornithologists, Biodiversity Centre for Wildlife Studies, Louisiana Pacific, and the Pacific Wildlife Foundation, as well as all of the volunteer participants who gathered data for the project.

We would also like to thank contributing partners:
Washington Department of Fish and Wildlife- Mike Schroeder and Derek Stinson
National Park Service- Tara Chestnut and Jason Ransom
U.S. Geological Survey- Betsy Glenn

Many thanks to our peer and partner reviewers: Michael Schroeder, Derek Stinson, Chris Anderson, Stefanie Bergh, Clait Braun, Rick Hoffman, and Gregg Wann

Special thanks to Betsy Glenn for generating the climate data. We are especially grateful to Michael Schroeder for providing years of observations, many thought-provoking ideas, and his tireless patience with our many questions.

EXECUTIVE SUMMARY

The Mount Rainier white-tailed ptarmigan (*Lagopus leucura rainierensis*) is a small alpine grouse, which molts frequently throughout the year to remain cryptic. They are white in winter, mottled with brown and white in spring, and brown in summer. There are currently four other subspecies of white-tailed ptarmigan recognized, including the southern white-tailed ptarmigan (*Lagopus leucura altipetens)*, the Kenai white-tailed ptarmigan (*L. l. peninsularis*), the Vancouver Island white-tailed ptarmigan (*L. l. saxatilis*), and the northern white-tailed ptarmigan (*L. l. leucura*). In 2010, the Service was petitioned to list the Mount Rainier white-tailed ptarmigan, and the southern white-tailed ptarmigan as threatened under the Endangered Species Act of 1973, as amended. In 2012, the Service issued a positive 90-day finding indicating that listing the southern white-tailed ptarmigan and the Mount Rainier white-tailed ptarmigan may be warranted.

White-tailed ptarmigan are resident or short-distance elevation migrants with numerous adaptations for snow and extreme cold in winter, including feathered feet, a low thermal neutral zone, low evaporative cooling efficiency, high metabolic rate, and behavioral adaptations including snow roosting. In summer, they are intolerant of heat, and remain close to cool microsites such as the edges of snowfields, the shade of boulders, or near streams where temperatures are cool. Incubating females, however, are often exposed to harsh summer sun and high temperatures because they must remain on nests.

In the North Cascades, one observational study conducted in July and August noted Mount Rainier white-tailed ptarmigan occupy areas of short-stature alpine vegetation (<25 cm in height) with red and white heather and dwarf huckleberry, boulders, and snowfields. Otherwise, we have no specific studies on habitat use by Mount Rainier white-tailed ptarmigan. Based on topographic, climatic, and vegetation similarities to the Sierra Nevada of California and Vancouver Island, British Columbia, we expect their behavior and habitat use patterns to be similar to white-tailed ptarmigan in these other areas. The population in the Sierra Nevada of California is a transplanted population of southern white-tailed ptarmigan that rapidly expanded throughout the range in the first 18 years following release. We use these populations as surrogates frequently throughout our analysis, and where we have no information for these surrogates, we incorporate information on the well-studied southern white-tailed ptarmigan in its native range of Colorado.

For purposes of this status assessment, we have lumped habitat relationships into three seasons: breeding, post-breeding, and winter. Based on our limited information, we expect breeding territories consist of alpine areas with moist low-statured vegetation near snowbanks, streams, and boulder fields. These territories have abundant forage, including forbs for adults, and insects for younger chicks. We expect post-breeding habitat to contain boulder fields and snowbanks for their cool microclimates and hiding cover, with heather, moist forbs, sedges, and water in close proximity. Winter habitat for the Mount Rainier white-tailed ptarmigan has not been studied, and is the season in which we have the least confidence in using information from surrogate subspecies of white-tailed ptarmigan. Southern white-tailed ptarmigan are associated with tall willow shrubs along riparian areas and meadows in winter. However, these large expanses of willow are not found in the range of the Mount Rainier white-tailed ptarmigan. We predict they are associated with avalanche chutes and other forest openings in alpine and subalpine areas with willow, alder, or birch shrubs that protrude above the snow.

Two representation units and eight populations were delineated at an expert elicitation meeting based on observations, elevation, and vegetation from Landfire vegetation maps. We refined the boundaries of these units by selecting vegetation types on recently refined National Park Service vegetation maps, and Landfire vegetation maps for National Forest Service lands. Our refined unit maps contain nearly all observations of the species obtained from agency partners.

Key needs for Mount Rainier white-tailed ptarmigan populations have not been studied. Based on anecdotal observations in Washington, expert opinion, a study in the North Cascades, and research done on other white-tailed ptarmigan subspecies, we describe ten key attributes for resilient population units: 1) connectivity among seasonal use areas; 2) cool ambient summer temperatures; 3) a suitable hydrologic regime to support alpine vegetation; 4) winter snow quality and quantity; 5) abundance of forage; 6) cool microsites; 7) suitable population structure and recruitment; 8) adequate population size and dynamics; 9) total area of alpine breeding and post-breeding habitat; and, 10) total area of winter habitat. We developed tables of these key population needs, one or more measurable indicators of each population need (21 indicators in all), and defined categories of Poor, Fair, Good, and Very Good condition for each indicator based primarily on research conducted on surrogate subspecies of white-tailed ptarmigan. We also created influence diagrams of potential stressors and sources of stress to Mount Rainier white-tailed ptarmigan and their breeding, post-breeding, and winter habitat. Stressors included all population needs that are currently in Poor or Fair condition, or predicted to degrade to Poor or Fair condition in the foreseeable future. We worked with partners to identify sources of these stressors, and factors that cause them or facilitate their persistence.

To evaluate current condition, we input information for the current value of each indicator and assigned it to a condition category in site conservation planning workbooks adapted for single species resiliency analysis. Information was not available for current condition of many indicators, including all demographic indicators, which is a major shortcoming of our analysis. We obtained indicators of some bioclimatic variables for each population, particularly temperature and hydrologic patterns that maintain moist alpine vegetation. Abiotic variables were summarized by USGS across each population unit (excluding non-habitat areas of perennial ice and snow at the highest elevations). We also used glacial melt discharge as an indicator of hydrologic regimes necessary to support breeding and post-breeding habitat. We selected suitable alpine vegetation communities from the National Park Service (NPS) and Landfire maps and used the total area as the indicator of current breeding and post-breeding habitat for each population. We also used the estimated current size of alpine area developed using bioclimatic niche vegetation models and MC2 vegetation models to enable comparison with future alpine area projected with climate change. The workbooks summarize scores for indicators of population needs into a single score for each need, then summarize the scores for the needs by categories of size, condition, and landscape context, which are then summarized into a single resiliency score for each population. We evaluated the number of resilient populations to describe redundancy of populations for the species, and the existence of one or more resilient population in each unit to describe representation.

Based on the values available, current resiliency ratings are Good for Mount Rainier, North Cascades West, and North Cascades East population units. Resiliency ratings are Fair for Mount Adams, Goat Rocks, and Alpine Lakes population units. Redundancy is limited to six population units across the range of the subspecies. The Mount St. Helens population unit is extirpated as a result of the volcanic explosion in 1980, and the William O. Douglas population unit contains potential habitat, but we have no records of white-tailed ptarmigan in the area and consider occupancy unknown. Three extant population units occur in the southern representation unit and three extant population units occur in the northern representation unit. If a catastrophic event, such as another volcanic eruption, were to occur in in the either representation unit, two population units would remain, which is the lowest level of redundancy possible. Habitat for populations in the Southern Representation Unit are isolated and small in area. Anecdotal observations and expert opinion indicates there is only a small number of birds in all population units in the Southern Representation Unit, with the exception of the Mount Rainier population unit.

To evaluate future condition, we used the same workbooks that we used for current condition, but input indictor measurements based on modelled projections. Projections were for four different scenarios: 1) Projected climate change effects under Representative Concentration Pathway 4.5 with no management for Mount Rainier white-tailed ptarmigan populations or habitat; 2) Projected climate change effects under Representative Concentration Pathway 8.5 with no management for Mount Rainier white-tailed ptarmigan populations or habitat; 3) Projected climate change effects under Representative Concentration Pathway 4.5 with management to maintain Mount Rainier white-tailed ptarmigan populations and habitat; and, 4) Projected climate change effects under Representative Concentration Pathway 8.5 with management to maintain Mount Rainier white-tailed ptarmigan populations and habitat.

Under Scenario 1, the GCM 4.5 scenario without management actions designed to benefit white-tailed ptarmigan, projections for abiotic indicators such as temperature and hydrologic regimes, and habitat condition remain Good in 2069. However, vegetation projections (we were only able to obtain MC2 for this scenario) indicate the area of habitat would be Poor for all population units except the Mount Adams (which would be Good) and Mount Rainier (which would be Very Good).

Under Scenario 2, the GCM 8.5 scenario without management actions to benefit white-tailed ptarmigan, the Mount Rainier white-tailed ptarmigan would be extirpated because of a complete loss of breeding and post-breeding habitat in all but one population unit (Mount Rainier). These results are consistent between MC2 and Bioclimatic niche vegetation models. Projections for alpine habitat loss are supported by projections of altered hydrologic regimes in upper basins, which would negatively impact alpine vegetation. Resiliency of the sole remaining population on Mount Rainier under this scenario would be Good.

Under Scenario 3, the GCM 4.5 scenario with management actions to reduce negative effects of recreation and create climate microrefugia, projections for abiotic indicators such as temperature and hydrologic regimes, habitat condition would be mostly Good in 2069. However, bioclimatic niche vegetation projections (we were only able to obtain MC2 for this scenario) indicate no breeding or post-breeding season habitat would remain for any population unit, except the Mount Adams (Good) and Mount Rainier (Very Good) population units. Therefore, the management actions would serve to prevent or reduce the impact of additional stressors, but would not improve resiliency for any population.

Under Scenario 4, the GCM 8.5 scenario with management actions for white-tailed ptarmigan that create microrefugia and reduce negative effects of recreation, all population units would be extirpated, except the Mount Rainier, Mount Adams, and the North Cascades West population units. The North Cascades West population unit may support a small population of Mount Rainier white-tailed ptarmigan with Fair to Poor resiliency as a result of effective management actions to maintain that population unit. This additional population unit reflects the main difference between Scenario 4 and Scenario 2.

Although vegetation models yield different acreage projections, all scenarios project similar outcomes: one or two of the eight populations are likely to have breeding season habitat remaining by 2069. All scenarios project habitat for the Mount Rainier population unit will persist.

Much information for the Mount Rainier white-tailed ptarmigan is unavailable, and our only option was to rely on surrogate information from other subspecies of white-tailed ptarmigan for predicting habitat use patterns. Studies of habitat use patterns for the Mount Rainier subspecies, particularly in winter, are needed to understand current and projected future condition of populations. Demographic information is lacking, and we have no data on population sizes, trends, or population structure. Although long-term data sets are ideal, two or three years of population and habitat data would significantly improve our ability to forecast future conditions for this alpine dependent species. Currently-available anecdotal data could be used to model future distribution, and would provide valuable information while field studies are being conducted.

Contents

TABLE OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 Background

This report summarizes the results of a species status assessment (SSA) conducted for the Mount Rainier subspecies of white-tailed ptarmigan (*Lagopus leucura rainierensis*). In 2010, the Service was petitioned to list the southern white-tailed ptarmigan (*Lagopus leucura altipetens)* and the Mount Rainier white-tailed ptarmigan as threatened under the Endangered Species Act of 1973, as amended (Act). In 2012, the Service issued a positive 90-day finding on the petition to list the subspecies, having determined that the petition presented substantial scientific or commercial information indicating that listing the southern white-tailed ptarmigan and the Mount Rainier white-tailed ptarmigan may be warranted.

Once the Service issues a positive 90-day finding on a petition, we are required to complete a status review for the species based on the best available information at the time. A status review is required to be completed after a positive 90-day finding even if there is a dearth of information on a particular species/subspecies, as is the case with Mount Rainier white-tailed ptarmigan. For status reviews on data poor species, we often rely on information from closely related species to infer demographic and habitat needs, as well as an understanding of species' response to environmental and anthropogenic influence factors. These closely related species are often not perfect surrogates to our species under review, and we attempt to clearly identify uncertainties and assumptions related to the use of information from any particular surrogate. In spite of a less-than-perfect proxy, information on a surrogate's life history can be useful in enhancing our understanding and providing us a basic scientific underlayment for a status determination on the species under review. For our status review on Mount Rainier white-tailed ptarmigan, the best available information included surrogate information from the other subspecies of white-tailed ptarmigan, including southern white-tailed ptarmigan (*L. l. altipetens)*, Kenai white-tailed ptarmigan (*L. l. peninsularis*), Vancouver white-tailed ptarmigan (*L. l. saxatilis*), and northern white-tailed ptarmigan (*L. l. leucura*)), as well as other species of ptarmigan (rock ptarmigan (*Lagopus muta*) and willow ptarmigan (*Lagopus lagopus*). Best available information also often includes information from studies of a translocated population of white-tailed ptarmigan in the Sierra Nevada of California. We acknowledge that translocated populations may not always behave or react in the same ways as a natural population, and data from those populations may not accurately reflect the attributes of native populations. However, we are not attempting to reflect the attributes of the native Colorado population, but are using the information as a surrogate for the Mount Rainier white-tailed ptarmigan, which shares many habitat similarities with the Sierra Nevada. The Sierra Nevada population was studied over 18 years after translocation, and the population had spread and grown rapidly, indicating it was well-suited to its new environment.

This SSA Report is intended to provide the biological support for the decision on whether to propose to list the Mount Rainier white-tailed ptarmigan as threatened or endangered and, if so, whether to and where to propose designating critical habitat. The SSA Report does not result in a decision by the Service on whether this taxon should be proposed for listing as a threatened or endangered species under the Act. Instead, this SSA Report provides a review of the available information strictly related to the biological status of the Mount Rainier white-tailed ptarmigan. The Service will make the listing decision after reviewing this document and all relevant laws, regulations, and policies. The results of a proposed decision will be announced in the Federal Register, with appropriate opportunities for public input. In this document, we refer to the Mount Rainier white-tailed ptarmigan as a species because subspecies are treated as species for the purposes of evaluating taxa for listing under the Act.

1.2 Analytic Framework

The SSA report, the product of conducting an SSA, is intended to be a concise review of the species' biology and factors influencing the species, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA report to be easily updated as new information becomes available, and to support all functions of the Endangered Species Program. As such, if the species is listed under the Act, the SSA report will be a living document upon which other documents such as recovery plans and 5-year reviews will be based; supporting future decisions about the Mount Rainier white-tailed ptarmigan's listing status and, eventually, a post-delisting monitoring plan.

Using the SSA framework (Figure 1), we consider what a species needs to maintain viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation, collectively the 3Rs (Service 2016, entire; Smith *et al*. 2018, entire). For the purpose of this assessment, we generally define viability as the ability of the Mount Rainier white-tailed ptarmigan to sustain populations in its natural habitat over time. Resiliency, redundancy, and representation are defined as follows:

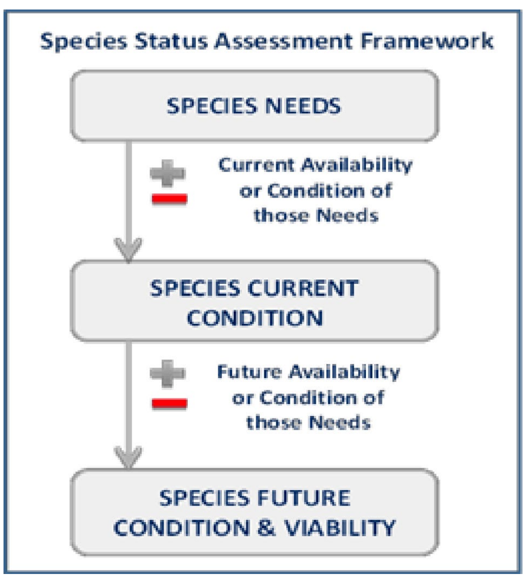


Figure 1. Species Status Assessment Framework

Resiliency means having sufficiently large populations for the species to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health—for example, population size and recruitment, if that information exists. Resilient populations are better able to withstand disturbances such as random fluctuations in recruitment (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of human activities.

Redundancy means having a sufficient number of populations for the species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations). Redundancy is about spreading the risk and can be measured through the duplication and distribution of populations across the range of the species. Generally, the greater the number of populations a species has distributed over a larger landscape, the better it can withstand catastrophic events.

Representation means having the breadth of genetic makeup of the species to adapt to changing environmental conditions. Representation can be measured through the genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human-caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of the species' morphology, habitat characteristics within the geographical range, or both.

The decision whether to list, downlist, or delist a species is based not on a prediction of the most likely future for the species, but rather on an assessment of the species' risk of extinction. Therefore, to inform this assessment of extinction risk, we describe the species' current biological status and assess how this status may change in the future to account for the uncertainty of the species' future. We evaluate the future biological status of the species by describing the future scenarios representing the plausible conditions for the primary factors affecting the species and forecasting the projected future condition for that scenario in terms of the 3Rs. As a matter of practicality, the full range of potential future scenarios and the range of potential future conditions for each potential scenario are too large to individually describe and analyze therefore our analysis does not include all possible futures.

2.0 SPECIES' INFORMATION

2.1 Species Description

The Mount Rainier white-tailed ptarmigan is a small alpine grouse that appears entirely white in winter, mottled with brown and white in spring, and brown and gray in summer. The birds molt with the seasons to provide camouflage as the amount of snow in their habitat changes. The white tail feathers remain white year-round and distinguish the white-tailed ptarmigan from other ptarmigan species (Braun et al. 2011, Distinguishing Characteristics section). According to Martin et al. (2015, Table 3), males and females share similar body size, shape, and winter plumage, with adult body lengths up to 13.4 inches (in) (34 centimeters (cm)) and body masses up to approximately 0.83 pounds (lbs) (378 grams (g)). However, Braun (2019, pers. comm.) who has measured the body mass of thousands of white-tailed ptarmigan during all seasons of the year, states that females may weigh up to approximately 1 lb (500 g) prior to egg laying, and that the body mass of adult males may exceed approximately 0.9 lb (400 g) in late fall and winter. Hoffman (2020, pers. comm.) stated that body mass ranges from approximately 0.75-0.9

lb (345-410 g) for males and approximately 0.77-0.94 lb (350-425 g) for females, depending on the time of year. During the winter, both males and females are stark white and difficult to distinguish from each other and from the background of snow, except for black eyes, dark toenails, and a black beak (Braun et al. 1993, Appearance section; Hoffman 2006, p. 12). As the snow melts and the breeding season begins, males' breast feathers turn dark brown and black, resembling a necklace, and their breeding plumage is more brown and gray than that of females. Both males and females have heavily feathered feet that act as snowshoes to support them as they walk across the snow (Martin et al. 2015, Nutrition and Energetics section).

2.2 Taxonomy & Genetics

The white-tailed ptarmigan is in the order Galliformes, family Phasianidae, and the subfamily Tetraoninae, which includes multiple grouse species (Hoffman 2006, p. 11; NatureServe 2011, p. 1). Other species of ptarmigan include rock ptarmigan and willow ptarmigan. There are five recognized subspecies of white-tailed ptarmigan in North America. The Mount Rainier white-tailed ptarmigan (*Lagopus leucura rainierensis*) occupies the Cascade Mountains of Washington and southwestern British Columbia, Canada. The southern white-tailed ptarmigan (*L. l. altipetens)* occupies the Rocky Mountains in Colorado, New Mexico, and historically, southern Wyoming. The Kenai white-tailed ptarmigan (*L. l. peninsularis*) extends from Canada into Alaska, and the Vancouver white-tailed ptarmigan (*L. l. saxatilis*) is restricted to Vancouver Island in Canada. The northern white-tailed ptarmigan (*L. l. leucura*) extends from northern Canada into Montana.

Multiple taxonomic authorities for birds recognize the validity of the five subspecies of white-tailed ptarmigan. The AOU recognized the five subspecies in their Checklist (AOU 1957, entire). Since 1957, the AOU has not conducted a review of its subspecific distinction and stopped listing subspecies as of the 6th edition in 1983. However, the AOU (1998, p. xii) recommends the continued use of its 5th edition (AOU 1957, entire) for taxonomy at the subspecific level. Based on their 1957 consideration of the taxon, the AOU still recognizes the Mount Rainier white-tailed ptarmigan as a valid subspecies. Additionally, the Integrated Taxonomic Information System (ITIS) (2019) and Cornell Lab of Ornithology's Clements Checklist (Clements et al. 2019) also recognize the five subspecies of white-tailed ptarmigan.

Based on a lack of comparative work, Braun et al. (1993, Systematics section) questioned the status and validity of the five subspecies of white-tailed ptarmigan. After examining museum specimens, Braun et al. suggested that the southern, Mount Rainier, and Vancouver Island white-tailed ptarmigan are similar in size and color, whereas the northern and Kenai white-tailed ptarmigan are similar in size and color (1993, Systematics section; (Hoffman 2006, p. 11). The 2015 Birds of North America online account for white-tailed ptarmigan indicates that the southern white-tailed ptarmigan is the largest of the subspecies in terms of body length, while Mount Rainier and Vancouver Island white-tailed ptarmigan are intermediate (though Mount Rainier white-tailed ptarmigan have slightly longer wings), and the northern and Kenai subspecies are the smallest. Braun et al. (1993, Systematics section) observed a gradation in size and color from south to north, with larger, darker-colored birds in the south. However, Braun et al. never published their results and thus, their questioning of the subspecies designations was not subjected to scientific peer review. Subsequently, a scientifically peer-reviewed study was conducted which reviews the genetics of white-tailed ptarmigan (Langin et al. 2018) using data from both microsatellites and single nucleotide polymorphisms. Their analyses found the southern white-tailed ptarmigan and Vancouver Island white-tailed ptarmigan were clearly distinct genetic groups, but the genetic divergence was less pronounced between Mount Rainier white-tailed ptarmigan, northern white-tailed ptarmigan, and Kenai white-tailed ptarmigan, which calls into question whether the taxonomic units of Mount Rainier white-tailed ptarmigan, northern white-tailed ptarmigan, and Kenai white-tailed ptarmigan are genetically-distinct groups or not (p. 1483). However, Langin et al. (2018, p. 1482) stated that, "Sampling was sparse in some areas – particularly mainland British Columbia, where multiple subspecies converge – making it infeasible to identify the start and end points of putative genetic groups." They also stated, "Finer resolution spatial sampling will be needed to determine whether Mount Rainier white-tailed ptarmigan, northern white-tailed ptarmigan, and Kenai white-tailed ptarmigan represent distinct groups, and, if so, the locations of the boundaries." Additional sampling may help determine if Mount Rainier white-tailed ptarmigan are a distinct genetic group that intermixes with northern white-tailed ptarmigan, or if the Washington/southern British Columbia area forms the periphery of a genetic cline. This would be a difficult distinction to prove, even with more sampling, given the less-pronounced level of divergence (Bohling 2019, in litt., p. 3). According to Langin et al. (2018, Figures S10 and S14), birds with Mount Rainier white-tailed ptarmigan ancestry are found on both sides of the international border, as are birds with northern white-tailed ptarmigan ancestry. This is not surprising, since there is no break in suitable habitat at the border. Therefore, it is likely that the range of the Mount Rainier white-tailed ptarmigan extends into British Columbia.

We recognize the lack of conclusory information, particularly morphological and genetic data, regarding the subspecific designation of Mount Rainier white-tailed ptarmigan. However, no newer data, including Langin et al. (2018), provides information which would negate the validity of the five subspecies identified by the AOU (1957). No revision of the taxonomy of white-tailed ptarmigan is currently proposed. Therefore, we are evaluating the Mount Rainier white-tailed ptarmigan, as described by the AOU (1957) in this Species Status Assessment. Lack of a habitat break at the international border suggests that the range of the species extends into British Columbia, and we are therefore including a small portion of British Columbia that is contiguous with habitat in Washington.

2.3 Life History, Mating System, and Sex Ratio

White-tailed ptarmigan are usually monogamous, but polygyny (one male with multiple females) and polyandry (one female with multiple males, a.k.a. extra-pair copulations) also occur on rare occasions (Benson 2002, p. 195; Braun and Rogers 1971, p. 33). Male to female sex ratio varies from 0.8 to almost 2 (Braun 1969, p. 42; Clarke and Johnson 1992, p. 624). Habitat quality and quantity likely influence sex ratio (Fedy and Martin 2011, p. 313).

2.3.1 Territory Establishment and Nesting

Males establish territories in early spring as soon as snow-free patches are available. Males are strongly territorial, and will exclude all other males. Females in Colorado arrive on breeding areas in late April to mid-May, which is when pairs form (Martin et al. 2015, Phenology section). Timing of breeding and nesting is driven by availability of forage plants, which occurs with snow melt on territories (Braun 1969, p. 55). Pair formation is usually stable once established, though females sometimes move to other territories after initial bonding (Martin et al. 2000, p. 509). Most pairs are similarly-aged adults or yearlings (Martin et al. 2015, Breeding section). Males will accompany females approximately 90 percent of the time between pair bonding and incubation (Martin et al. 2015, Sexual behavior section). If both members of a pair return to a territory the following year, they will usually keep the same mate (Schmidt 1988, p. 285-6; Martin et al. 2015, Breeding section).

Females begin egg-laying a few days after constructing the nest. Nests are typically located within the male's territory (Braun and Rogers 1971, p. 37; Giesen et al. 1980, p. 194), and are always on the ground, typically in areas that are snow-free by early June (Braun and Rogers 1971, p. 37). Nests are a shallow bowl made of dried vegetation that is collected within approximately 16 in (40 cm) of the nest, and typically contain several small feathers (Giesen et al. 1980, p. 195). Nests are constructed in rocky areas, meadows, willow thickets, and in the krummholz zone (Giesen et al. 1980, p. 195; Wiebe and Martin 1998b, p. 1139), usually with some lateral cover (Wilson and Martin 2008, p. 635-636). Because incubating hens are at higher risk of predation and concealed nests are more successful, most females will choose some amount of nest cover but with good escape routes, rather than selecting sites with more cover (Wiebe and Martin 1998b, p. 1142).

Due to the short breeding season, female white-tailed ptarmigan usually only nest once per season. However, if they lose their nest during the laying period or early incubation, they may lay a second or, rarely, a third clutch of eggs at another site within their territory (Choate 1963, p. 693; Giesen and Braun 1979, p. 217). Regardless, female white-tailed ptarmigan only raise one brood per year (Martin et al. 1989, p. 1789). White-tailed ptarmigan at alpine (Colorado) sites have smaller clutch sizes, lower fledging success rates, and are less likely to renest than willow ptarmigan in Alberta, Canada or British Columbia, Canada (Sandercock et al. 2005a, pp. 2182-2183). Furthermore, arctic willow ptarmigan had high fecundity and low adult survival, the opposite of alpine white-tailed ptarmigan, showing how life history traits of closely-related species can vary widely among these extreme environments across latitudes (Sandercock et al. 2005a, p. 2184). In addition, white-tailed ptarmigan show within-species variation across their latitudinal range, wherein white-tailed ptarmigan in the Yukon have the high fecundity of an r-selected species, while white-tailed ptarmigan in Colorado have the high survival of a K-selected species (Wilson and Martin 2011, p. 49). Nest site elevation varies with date of laying, cover type, aspect, and female body condition. Later nests are at higher elevations, rock nests are at higher elevations than sedge or willow nests, east-facing nests are higher than west-facing nests, and larger females in better condition nest at higher elevations (Braun and Rogers 1971, pp. 35-41; Wiebe and Martin 1998b. pp. 1142-1143).

2.3.2 Egg Laying, Incubation, and Parental Care

Older females lay their eggs before less-experienced females, initiating their clutches approximately 1-5 days sooner than younger females (Wiebe and Martin 1998a, p. 17). Breeding may not begin until the amount of snow cover is favorable for breeding, therefore egg-laying can be delayed if appropriate breeding habitat conditions don't occur until later in the season (Martin and Wiebe 2004, p. 181). First clutches are typically 4-9 eggs, with smaller replacement clutches

(2-7 eggs). These numbers vary based on population, age of the female, and clutch initiation date (Wiebe and Martin 1998a, p. 20; Wiebe and Martin 1998a, p. 140; Martin et al. 2015, Table 1 and Appendix 2; Wilson and Martin 2011, p. 463; Wilson and Martin 2012, p. 3). Only the female incubates the eggs, which usually begins once the 2nd to last or last egg has been laid (Martin et al. 2015, Incubation section). Incubation lasts 22-25 days, with larger clutches taking longer (Wiebe and Martin 2000, p. 467; Martin et al. 2015, Incubation section). Severe weather may also extend total incubation time (Martin and Wiebe 2004, pp. 180, 183). Hens leave the nest if they need to feed or defecate, and may be away from the nest for up to 30-minutes before sunrise and after sunset, or for shorter periods midday (Giesen and Braun 1979, p. 215; Schmidt 1988, p. 290; Wiebe and Martin 1997, pp. 221-222; Wiebe and Martin 2000, p. 466). During these times, females fly away from the nest and spend most of their time feeding. Males will join them, remaining vigilant and accompanying the females when they fly back to an area at or near the nest (Schmidt 1988, pp. 278, 288-290; Wiebe and Martin 1997, p. 222). Mean date of hatch for first nests in Colorado is approximately mid- to late-June to mid- to late-July, while median hatch date is approximately late June to late July (Giesen et al. 1980, p. 190), but timing of breeding at Colorado sites have advanced an average of 1.9-3.7 days per decade since 1968 (Wann et al. 2016, p. 11).

Older females lay their eggs before less-experienced females, initiating their clutches approximately 1-5 days sooner than younger females. Breeding may not begin until the amount of snow cover is favorable for breeding, therefore egg-laying can be delayed if appropriate breeding habitat conditions don't occur until later in the season. First clutches are typically 4-9 eggs, with smaller replacement clutches (2-7 eggs). These numbers vary based on population, age of the female, and clutch initiation date (Wiebe and Martin 1998a, p. 140; Martin et al. 2015, Table 1 and Appendix 2; Wilson and Martin 2011, p. 463; Wilson and Martin 2012, p. 3). Only the female incubates the eggs, which usually begins once the 2nd to last or last egg has been laid (Martin et al. 2015, Incubation section). Incubation lasts 22-25 days, with larger clutches taking longer (Wiebe and Martin 2000, p. 467; Martin et al. 2015, Incubation section). Severe weather may also extend total incubation time (Martin and Wiebe 2004, pp. 180, 183). Hens leave the nest if they need to feed or defecate, and may be away from the nest for up to 30-minutes before sunrise and after sunset, or for shorter periods midday (Giesen and Braun 1979, p. 215; Schmidt 1988, p. 290; Wiebe and Martin 1997, pp. 221-222; Wiebe and Martin 2000, p. 466). During these times, females fly away from the nest and spend most of their time feeding. Males will join them, remaining vigilant and accompanying the females when they fly back to an area at or near the nest (Schmidt 1988, pp. 278, 288-290; Wiebe and Martin 1997, p. 222). Mean date of hatch for first nests in Colorado is approximately mid- to late-June to mid- to late-July, while median hatch date is approximately late June to late July (Giesen et al. 1980, p. 190), but timing of breeding at Colorado sites have advanced an average of 1.9-3.7 days per decade since 1968 (Wann et al. 2016, p. 11).

2.3.3 Hatching, Brooding, Rearing, and Chick Development

Chicks are precocial, meaning their eyes are open when they hatch. Their bodies are covered with dense down, including their feet (Martin et al. 2015, Young Birds section). The hen leaves the nest with her chicks within 6-12 hours after all eggs have hatched, usually in the middle of the day, and do not return to the nest (Martin et al. 2015, Young Birds section).

Only females brood the chicks, and for their first 2-3 weeks in particular, chicks are dependent on the hen for thermoregulation, habitat selection, and predator protection (Martin et al. 2015, Fledgling Stage section). Chicks are capable of flight at 10-12 days of age, when they are approximately 9 percent of the mass of an adult (Martin et al. 2015, Young Birds section). Their juvenile feathers start growing in after 17 days (Choate 1960, p. 95; Martin et al. 2015, Young Birds section), and their winter white feathers start growing in at age 8-10 weeks, when they will continuously molt until mid-October to early November (Martin et al. 2015, Young Birds section).

Broods remain within approximately 328-984 feet (ft) (100-300 meters (m)) of the nest for the first few days, but gradually move up to about 2.5 miles (mi) (4 kilometers (km)) away, depending on where forage and cover for chicks is found (Braun 1969, p. 140; Schmidt 1988, p. 291; Giesen and Braun 1993, p. 74). Broods generally move upslope as chicks grow, in order to access newly emerged forage plants that are important for older chicks (Hoffman 2006, p. 21). Young broods must reach suitable brood-rearing habitat by walking, thus any gaps between nesting and brood-rearing habitat could be detrimental to chick survival (Hoffman 2020, pers. comm.). Chicks remain with females for 8-10 weeks, and sometimes through the winter (Martin et al. 2015, Fledgling Stage section). Growth slows at about 12-14 weeks of age (Martin et al. 2015, Young Birds section).

2.3.4 Survival and Lifespan

Population, life history, age, gender, location, and management all influence lifespan and survival (Braun 1969; Sandercock et al. 2005a, 2005b; Wilson and Martin 2011, 2012). Records of longevity for wild birds include a 12-year-old female and a 15-year-old male (Martin et al. 2015, Life Span and Survivorship section). Breeding season mortality is higher for females than for males (Martin et al. 2015), but is assumed to be highest for both sexes during migration between breeding and wintering areas in the fall and spring (Braun and Rogers 1971). Annual survival rates for adult ptarmigan are higher in Colorado than in the Yukon (Wilson and Martin 2011, p. 466). Survival rates change from year to year and among populations, with no consistent trend or pattern; in one Colorado study the author found that subadults have a higher survival rate than adults (Wann et al. 2014, p. 559), while in another Colorado study, the authors found that 2-year-old females survived longer than younger or older females, though the difference was not statistically significant (Sandercock et al. 2005b, p. 16). Studies in British Columbia showed equivalent survival across genders (Hannon and Martin 2006, p. 426), but rates varied once birds were banded (Martin et al. 2015; Life Span and Survivorship section). Juvenile survival of ptarmigan during their first fall and winter is usually lower than adult survival (Choate 1963, p. 696; Geisen and Braun 1993, p. 75; Hannon and Martin 2006, p. 423).

2.3.5 Diet

Adult white-tailed ptarmigan, as well as chicks more than approximately five weeks old, are herbivorous (May 1975, pp. 28-29). Crop samples from white-tailed ptarmigan in Washington include samples from Mount St. Helens, Bald Mountain, and Barron (Table 1). Plant items in crops consisted of leaves, buds, and catkins of willow (*Salix)*; fruit of *Carex*, *Poa*, and *Cassiope;* and leaves of *Ranunculus*, (Table 1). White-tailed ptarmigan in the North Cascades were observed eating, in order of preference: dwarf huckleberry (*Vaccinium deliciosurri*), red mountain heather (*Phyllodoce empetriformes*), black-headed sedge (*Carex nigricans)*, white mountain heather (*Cassiope mertensiana*), crowfoot (*Leutkea pectinata*), Tolmie's saxifrage (*Saxifraga tolmiei*), spiked wood rush (*Luzula spicata*), and mosses. We found no other reports of Mount Rainier white-tailed ptarmigan diet. The remainder of our discussion of diet is based on findings from other subspecies of white-tailed ptarmigan.

Table 1. Diet of Mount Rainier white-tailed ptarmigan from crop samples (Weeden 1967, entire).

	Bald Mountain (n=7) September 5, 1920		Barron (n=1) August 21, 1920		Mount St. Helens (n=2) June 11, 1941	
Plant species and parts	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)	Frequency (%)	Weight (%)
Salix spp. (buds and twigs)	86	81				
Carex (fruit)	29	10				
Cassiope (fruit)	29	7				
Poaceae (fruit)			100	37		
Ranunculus (leaves)			100	54		
Unidentified			100	9		
Salix spp. (leaves)					100	92
Carex, Poa (fruit)					50	7

During winter, the buds, leaves, and twigs of willow shrubs protruding through the snow are a mainstay in the diet of white-tailed ptarmigan in many parts of their range. When willow is absent, the birds usually eat birch or alder; but they occasionally eat other plants, such as alpine bistort (*Bistorta vivipara*) and alpine dryad (*Dryas octopetala*) (Bailey 1927, p. 201; Weeden 1967, p. 305; May and Braun 1972, pp. 1181-1185; Moss 1973, p. 296). Winter foraging occurs in areas where snow is absent or where plants are tall enough to be above the snow (Braun and Schmidt 1971, p. 242). Grit is important at this time of year to digest rough willow and other shrubs (Braun 2019, pers. comm.); (May and Braun 1972, p. 1181; May and Braun 1973, p. 56). In the Sierra Nevada, white-tailed ptarmigan have been observed eating buds of aspen in winter (Padget 1989, personal communication). Weeden (1967, p. 307) suggests the increasing abundance of *Alnus* moving northwest from Colorado to Alaska, and interspecific interactions with rock and willow ptarmigan account for the dominance of *Alnus* in the winter diet of Alaskan white-tailed ptarmigan. How these patterns may apply to Mount Rainier white-tailed ptarmigan is unclear, as *Alnus* is abundant in their range, but willow ptarmigan do not occur in their range and rock ptarmigan occur only in low numbers at the extreme northern edge of their range.

In spring and summer, adults forage on forbs and graminoids (grass or grass-like plants, including grasses (Poaceae), sedges (Cyperaceae), and rushes (Juncaceae). Summer diet varies across the range of the species. A comparative study of diets of ptarmigan in Rocky Mountain National Park and the Sierra Nevada (Clarke and Johnson 2005, entire) revealed that ptarmigan in different ecological settings select diets with similar energy content but with different proportions of protein, carbohydrates, and nutrients. Birds in both areas included significant amounts of dwarf willow in their diets, but white-tailed ptarmigan observed in the Rocky Mountains had a more diverse mix of species, with nine species making up 99 percent of the average diet. These nine species included: *Acomastylis rossii* (alpine avens flowers), alpine bistort bulbils, alpine dryad flowers, *B. bistortoides* (American bistort bulbils), *Trifolium dasyphyllum* (alpine clover flowers and leaves), *Ranunculus adoneus* (snow buttercup flowers and leaves), *Lidia obtusiloba* (alpine sandwort flowers), *T. nanum* (dwarf clover flowers and leaves), and *Salix* spp. (alpine willow species leaves). Just two species made up 99 percent of the diet in the Sierra Nevada: a dwarf willow (*Salix anglorum*) made up 92 percent, and Jones' sedge (*Carex jonesii*) made up 7 percent (Clarke and Johnson 2005, p. 173).

Chicks less than 3 weeks old primarily eat invertebrates (May 1975, p. 28), though they may also eat flowers and leaves of forbs Chicks learn what to eat from their mothers, who select foods higher in protein (Clarke 2010, p. 27), which is important for chick growth and development (Robbins 1983, p. 148). Female white-tailed ptarmigan in Colorado select their nest locations based on high insect abundance, especially leafhoppers (Cicadellidae), over high vegetation cover, likely to meet the food requirements of their chicks (Spear et al. 2020, p. 182). Insect abundance is related to plant growth, and was correlated with normalized difference vegetation index (NDVI), an index of plant growth, in Colorado (Wann 2017).

2.3.6 Winter Ecology and Adaptations to Snow

White-tailed ptarmigan spend almost their entire lifecycles in alpine ecosystems and are well adapted to survive in cold environments (Johnson 1968, p. 1011; Hoffman 2006, p. 45 12; Storch 2007, p. 4). They molt into white plumage in winter, which effectively camouflages them against white snow ((Ligon 1961, p. 87; Braun et al. 1993, Distinguishing Characteristics section). Their winter plumage also has different reflective and absorptive properties, which helps the birds regulate body temperature (Hoffman 2006, p. 31). Low evaporative efficiencies prevent the loss of body heat (Johnson 1968, p. 1011). Additionally, snowshoe-like, feathered feet allow white-tailed ptarmigan to save energy by walking on top of snow rather than flying, which is energetically expensive (Storch 2007, p. 4).

White-tailed ptarmigan also exhibit behavioral adaptations to snow. Snow roosts are important for insulation and protection from wind during winter storms (Braun et al. 1976, p. 7; Wang et al 2002, p. 85). Areas used for night roosts were located in soft snow 300 mm or greater in depth; and night snow roosts had an average depth of 160 mm (range 90-270) from snow surface to the bottom of the roost (Braun and Schmidt 1971, p. 245). Snow quality affects their ability to burrow into the snow, and is believed to be important for winter survival in southern white-tailed ptarmigan (Braun and Schmidt 1971, p. 245). Wintering ruffed grouse (*Bonasa umbellus*) also use snow roosts, and individuals roosting in snow burrows had lower fecal corticosterone metabolite levels than those roosting outside of snow burrows, indicating the birds using the snow roosts were less stressed; corticosterone levels were lowest where snow depth was high (Shipley 2019, no pagination).

The different seasonal plumages effectively camouflage Mount Rainier white-tailed ptarmigan against white snow in winter, and alpine vegetation and rocks in the summer (Ligon 1961, p. 87); Braun et al. 1993, Distinguishing Characteristics section). The seasonal plumages also have different reflective and absorptive properties of the feathers to help the birds regulate body temperature (Hoffman 2006, p. 31). Metabolic rates are low, allowing the birds to gain weight during the winter (Hoffman 2006, p. 31). Low evaporative efficiencies prevent the loss of body heat (Johnson 1968, p. 1010: Hoffman 2006, p. 31). Additionally, snowshoe-like, feathered feet allow white-tailed ptarmigan to save energy by walking on top of snow rather than flying, which is energetically expensive (Storch 2007, p. 4).

2.4 Habitat

Habitat use by white-tailed ptarmigan varies by season. Breeding, territory establishment, and nesting all occur on snow-free areas in the male's territory, with nesting starting in early June in Colorado (Braun and Rogers 1971, p. 35; Giesen et al. 1980, p. 194). Young broods often occupy a transition zone between the upper limits of territories and the lower limits of summer use sites (occupied by males and unsuccessful females). Broods will eventually use the same summer use sites, but tend to remain separate (Hoffman 2019, pers. comm.). The birds form flocks and inhabit windswept ridges when breeding is finished, and then move downslope to winter habitat by late October in Colorado (Hoffman and Braun 1977, p. 108). To simplify analysis and presentation, we have lumped this variation into three distinct seasons in which habitat use patterns are similar among birds: 1) breeding, including territory establishment, nesting, and the early brood-rearing period; 2) post-breeding, including the period after breeding when flocks form, which may include some older broods; and 3) winter.

Habitat use by white-tailed ptarmigan also varies by geographic region. Climate, geologic parent material, soils, and vegetation vary widely between the areas where white-tailed ptarmigan are found. Unfortunately, we have very little information (one observational study) on habitat use in the range of the Mount Rainier white-tailed ptarmigan. The area with the most similar climate and vegetation, as well as white-tailed ptarmigan with genetic affinity most similar to the Mount Rainier subspecies is the mainland area of British Columbia, but no habitat use studies on white-tailed ptarmigan have been conducted in that area.

The most information available on habitat use by white-tailed ptarmigan comes from the Rocky Mountain area, and in many instances, the southern white-tailed ptarmigan will necessarily be relied upon as a surrogate species for this assessment. The Southern Rocky Mountains are very different from the Cascades, however. They are geologically much older; less steep; contain a greater diversity of plant species; and have an interior climate with colder, drier winters, and summers influenced by monsoonal weather from the Gulf of Mexico (Zwinger and Willard 1972, pp. 119-120). The climate is continental, with more extremes in temperature than the Cascades (Appendix A).

Geographically, the Cascade Range is closest to Vancouver Island, and many vegetation communities are shared between the Cascades and Vancouver Island, particularly in the northern part of the Cascades. However, habitat on Vancouver Island is low elevation, fragmented, and has a maritime climate (Jackson et al. 2015, p. 3).

Like the Cascades, the Sierra Nevada is a young mountain range, long from north to south and narrow from east to west, with a steep crest, oriented linearly and parallel to the Pacific Coast, creating a strong rainshadow effect and a drier climate on the eastern flank. Snow is deep and wet in the Sierra Nevada, although winter precipitation is not as extreme as the Cascades (Appendix A). Of the surrogate species and populations for which we have habitat information, the Sierra Nevada is most likely to be similar to the Cascades due to this deep, wet snow and fragmented alpine areas (Braun 2019, pers. comm.). As the climate of the Cascades becomes warmer with climate change, we expect it will become more similar to the Sierra Nevada.

For each of the following sections on seasonal habitat use, we first describe what we know about ptarmigan habitat in the Cascades. We often must rely primarily on habitat studies conducted on other subspecies of white-tailed ptarmigan in the most similar environments: the Sierra Nevada of California (an introduced population of southern white-tailed ptarmigan) and Vancouver Island, Canada (Vancouver Island white-tailed ptarmigan). When information for those populations are not available, we use information from the Rocky Mountains of Colorado (southern white-tailed ptarmigan),Glacier National Park, Montana and Alberta, Canada (northern white-tailed ptarmigan), and the Yukon territory of Canada (Kenai white-tailed ptarmigan). We describe habitat use patterns that appear consistent across the range of the species wherever possible. For those patterns that appear to vary regionally, we are relying on research conducted on Vancouver Island and in the Sierra Nevada.

Of 917 observations of Mount Rainier white-tailed ptarmigan in our database, 46 percent were in the North Pacific Alpine and Subalpine Bedrock and Scree Landfire vegetation type, followed by 19 percent in the North Pacific Dry and Mesic Alpine Dwarf-Shrubland Landfire vegetation type, and 12 percent in the M63 Sparse Alpine Vegetation NPS vegetation type (Appendix B). These types represent vegetation types similar in structure to those found in the post-breeding season in the Sierra Nevada, and may reflect the timing of anecdotal observations in late summer, during the post-breeding season. Further analysis should categorize these observations by season.

Habitat models of Mount Rainier white-tailed ptarmigan habitat are limited to one MaxEnt species distribution model, constructed using 800 Mount Rainier white-tailed ptarmigan presence-only sightings and eight predictor variables in Washington State (McFadden-Hiller 2017, entire). This model combined white-tailed ptarmigan observations from all seasons, but most observations in the database were from the breeding and post-breeding seasons. Predictor variables included land-cover type, topographic, and bioclimatic variables. A principal component including elevation and mean annual temperature predicted white-tailed ptarmigan occurrence best. Vegetation communities and micro-scale variables were not included in this statewide analysis.

2.4.1 Breeding and Brood-Rearing habitat

Mount Rainier white-tailed ptarmigan habitat on Sourdough Ridge, North Cascades National Park, in July and August; was similar to northern white-tailed ptarmigan habitat in Montana described as “Stable areas of rocks and ledges where alpine vegetation is well developed – moist, lush area with low-growing plants and ample rock cover” (Skagen 1980, entire). The habitat along Sourdough ridge spans the gradient from “dry, rocky, windswept areas to perpetually wet and mossy streamside areas" but becoming drier by mid-August (Skagen 1980, p. 4). Ptarmigan were rarely seen in vegetation over 25 cm in height, and were often associated with the edges of snowfields, but rarely used the snow itself (Skagen 1980, p. 4).

A study on southern white-tailed ptarmigan introduced in the Sierra Nevada found the predominant characteristics of breeding season habitat were cover of dwarf willow, subshrubs[1], herbs, and mosses; and proximity to water and willow shrubs (Frederick and Gutierrez 1992, p. 895). Although not statistically significant, white-tailed ptarmigan were frequently observed in areas with boulders > 30 cm diameter and fractured rock shelves (Frederick and Gutierrez 1992, p. 899). Similarly, the most reliable ptarmigan habitat model for Vancouver Island included positive relationships with boulder cover, ericaceous shrub[2] cover, graminoid cover, forb cover, shrub cover, and proximity to water (Fedy and Martin 2011, p. 311). Therefore, across both the areas most similar to the Cascades (the Sierra Nevada and Vancouver Island), cover of moist forbs, short-statured shrubs (particularly ericaceous shrubs), boulders, and proximity to water are the most important characteristics of breeding territories. We therefore expect breeding territories of Mount Rainier white-tailed ptarmigan also exhibit these characteristics. We also expect where dwarf willow occurs within their range, Mount Rainier white-tailed ptarmigan are likely to use it.

As noted earlier, males establish white-tailed ptarmigan territories in late April to early May, as soon as snow-free areas are available. Early in the breeding season, most territories are situated near treeline and are centered around stands of willows. Appearance of snow-free areas determines the timing of ptarmigan nesting in the Sierra Nevada (Clarke and Johnson 1992, p. 625). Similarly, in Colorado, ptarmigan nesting appears indirectly related to snowmelt timing because hens do not begin nesting until they have molted, and molt is affected by snowmelt timing (Braun and Rogers 1971, p.36). Where white-tailed ptarmigan co-occur with rock ptarmigan in the Yukon, they typically breed on steeper slopes in high alpine habitat with a mixed cover of rock and low vegetation

2.4.1.1 Vegetation communities

Breeding and brood-rearing habitat of Mount Rainier white-tailed ptarmigan is within the alpine zone, defined by treeline at its lower elevation limit, and permanent snow or barren rock at its upper elevation limit. The alpine zone is a narrow band of sparsely distributed vegetation, including patches of sedge-turf communities, subshrubs, or krummholz[3] interspersed between snowfields, talus slopes, and fellfields (Douglas and Bliss 1977, p. 115). Snowpack and timing of snowmelt, temperature, soil properties, and topography are the primary determinants of vegetation distribution, structure, and composition in the Cascades (Douglas and Bliss 1977, entire). Snow cover provides moisture for plant growth during the dry summers, and the depth and duration of the snowpack has a strong influence on soil moisture, phenology, and the distribution of plant communities (Canaday and Fonda 1974, entire; Evans and Fonda 1990, entire). In the North Cascades, where environmental gradients are steep due to complex

---

[1] Shrubs < 30 cm tall.
[2] Ericaceous shrubs are those that belong to the family Ericaceae, commonly known as the heath family.
[3] Krummholz trees are stunted and deformed by exposure to high, freezing winds in the subalpine treeline zone. Trees in this zone survive where they are sheltered by rock formations or snow cover.

topography and heavy snowfall, a mosaic of vegetation communities occurs on the landscape (Douglas and Bliss 1977, p. 141).

Treeline defines the lower elevation of the alpine zone used by white-tailed ptarmigan during breeding and post-breeding seasons. Treeline (the highest elevation with upright trees) is higher in elevation than timberline (the highest elevation with continuous forest). Both timberline and treeline vary with both latitude and aspect across the rugged topography of the Cascade Mountains (Franklin and Dyrness 1988; Körner and Paulsen 2004). Timberline elevation decreases with increasing latitude and is lower in the western edge of the Cascade Range than the east (Franklin and Dyrness 1988, p. 263). In the North Cascades, the lower limit of the alpine zone ranges from 6,400 ft. (1,950 m) on the west side of the range to 6,900 ft. (2,100 m) on the east side (Douglas and Bliss 1977, p. 115). In the North Cascades, continuous forest ends at about 4,200 ft (approximately 1,280 m) on northern slopes and approximately 5,200 ft (1,580 m) on southern slopes (Douglas 1972, p. 148). In Mount Rainier National Park, timberline ranges from 5,400 ft (1,646 m) at Paradise in the southern portion of the park to approximately 6,400 ft (1,951 m) at Sunrise in the northeast portion of the park. Treeline elevations vary from 6,890 ft (2,100 m) at Paradise to approximately 6,000 ft (1,840 m) at Spray Park in the northwest section of the park.

In the North Cascades, the upper limit of the alpine zone, (the highest elevation of continuous cover of alpine vegetation) is 7140 ft. (2,176 m) on the West side and 8530 ft. (2,600 m) on the East side (Douglas and Bliss 1977, p. 115). Above these elevations, sheer rocky slopes, snowfields, and glaciers restrict the establishment of continuous vegetation (Douglas and Bliss 1977, p. 115).

White-tailed ptarmigan in the North Cascades were found in vegetation communities of mountain heather (*Phyllodoce empetriformis* and *Cassiope mertensiana*), dwarf huckleberry (*Vaccinium deliciosum*), crowfoot (*Leutkea pectinata*), sedge (*Carex nigricans, C. spectabilis*), and Tolmie's saxifrage (*Saxifraga tolmiei*) (Skagen 1980, p. 2). On Vancouver Island, breeding season habitat includes alpine heather and subalpine heather communities with tree islands of spruce (*Picea* spp.) or subalpine fir (*Abies lasiocarpa*) distributed within the heather (Martin et al. 2004, p. 239). Ninety-two percent of opportunistic detections on Vancouver Island were in the Coastal Mountain-heather alpine biogeoclimatic zone and all but one of the remainder of detections were within the Mountain Hemlock zone (Jackson et al. 2015, p. 5)

In the Sierra Nevada of California, white-tailed ptarmigan select for mesic alpine vegetation communities, during the breeding season. Moist plant alliances, particularly those with dwarf willow (e.g., arctic willow (*Salix anglorum* var. *antiplasta*) or ericaceous subshrubs were used significantly more often than other alliances, and the *Salix anglorum var antiplasta* alliance was significantly more frequent in used plots than unused plots (Frederick and Gutierrez 1992, p. 89). White-tailed ptarmigan at these sites selected against the drier plant alliances (*Carex breweri-Calyptridium umbellatum* and *Arenaria kingii-Senecio werneriaefolius*), which were significantly more frequent in unused than used plots. At the plant association level, white-tailed ptarmigan used the Mertens cassiope-Brewer heather (*Cassiope mertensiana-Phyllodoce breweri*) association most frequently; other associations used included Mt. Dana sedge-little elephant's head (*Carex subnigricans-Pedicularis attollens*), mountain carpet clover-alpine cat's tail (*Trifolium monanthum-Phleum alpinum*), arctic-alpine snow willow (*Salix nivalis*), Heller's sedge-Suksdorf's bluegrass (*Carex helleri-Poa suksdorfii*), and broad-seeded rockcress-Sierra penstemon (*Boechera platysperma-Penstemon heterodoxus*) (Frederick and Gutierrez 1992, p. 894). Similarly, in Montana, moist vegetation less than 18 inches (46 cm) tall, and rocks 6-24 inches (15-61 cm) diameter were present in all areas heavily used by ptarmigan (Choate 1963, p. 686).

In Colorado, nesting territories were found in krummholz, Sedge-Avens (*Carex-Geum*) rock meadows, Sedge-Avens-Clover (*Geum-Carex-Trifolium*) meadows, Avens-Meadow Grass (*Geum-Poa*) meadows, and Kobresia-Sedge-Avens (*Kobresia-Carex-Geum*) meadows (Braun, and Rogers 1971, p. 16). At the two sites with long term demographic data (Mount Evans in Clear Creek County, Colorado, and Trail Ridge in Rocky Mountain National Park), low-growing willow (*Salix* spp.) and Englemann spruce (*Picea engelmannii*) predominated the vegetation at lower elevations, while herbaceous forbs (e.g.,alpine avens(*Geum rossii*), knotweeds (*Polygonum* spp.), *Ranunculus* spp.), sedges (e.g., *Carex* spp., *Kobresia* spp.), and grasses (e.g., *Deschampsia* spp., *Poa* spp., *Trisetum* spp.) predominated at higher elevations (Wann 2017, p. 7).

2.4.1.2 Water and snow

Proximity to water is an important characteristic of breeding and brood-rearing habitat in most areas across the range of the species (Choate 1963, p. 687; Frederick and Gutierrez 1992, p. 893). Distance to water was an important variable in habitat models for both the Sierra Nevada and Vancouver Island (Frederick and Gutierrez 1992, p. 895; Fedy and Martin 2011, p. 311). As noted earlier, these areas have the most similar climate and vegetation to the Cascades. White-tailed ptarmigan feed and loaf near surface seepage or alpine pools (Weeden 1959, p. 59). However, distance to free-standing water was not a predictor for patches around nest sites in Colorado (Spear 2017, p. 178). Differences in climate may explain the differences among regions, with drier climates requiring more standing water to maintain moist vegetation for forage.

Like water, snow provides moisture for forbs and insects. Both deep snow and lack of snow-free areas have been associated with reduced breeding success (Clarke and Johnson 1992, entire). Mount Rainier white-tailed ptarmigan have been observed using edges of snow-free patches on upland slopes extensively for foraging and roosting during spring and summer (Skagen 1980, p. 4). Southern white-tailed ptarmigan in the Sierra Nevada also use the edges of snow banks extensively (Frederick and Gutierrez 1992, p. 893). In Alberta, white-tailed ptarmigan fed and loafed near melting snowbanks (Weeden 1959, p. 59). However, distance to snow was not a predictor for patches around nest sites in Colorado (Spear 2017, p. 178). As with water, differences in climate may explain the differences among regions, with drier climates requiring more snowmelt to maintain moist vegetation for forage.

2.4.1.3 Boulders/rocks

Prominent rocks were used for vigilance and display behaviors by white-tailed ptarmigan in the North Cascades (Skagen 1980, pp. 7, 13, 16, 17). Rocks were used as cover in the same study (Skagen 1980, pp. 17-19). Boulder cover was also an important variable in habitat models on

Vancouver Island (Fedy and Martin 2011, p. 311), Montana (Choate 1963, p. 686), and range-wide (Weeden 1959, p. 120).

2.4.1.4 Nest site characteristics

Nest site characteristics have not been described for Mount Rainier white-tailed ptarmigan. Other subspecies of white-tailed ptarmigan usually place nests close to cover on one side; of 331 nest sites, the dominant cover type included rock (45 percent), followed by willow (33 percent), sedge (17 percent), and conifer krummholz (5 percent) (Wiebe and Martin 1998b, p. 1139). Spear et al. (2020, p. 181) reported that ptarmigan selected for nests at lower elevations and with low graminoid cover. Nest success is associated with steep slopes and lateral cover (Wiebe and Martin 1998b, p. 1142). However, cover presents a trade-off between the protection from predation it provides for the eggs, and an increased risk of predation to females, who have a difficult time escaping when cover blocks an escape route (Wiebe and Martin 1998b, p. 1142). Nest cover also provides protection from wind, and mediates extreme temperature changes found in exposed nests. Microclimate may determine nest site selection (Wiebe and Martin 1998b, p. 1142). Hens may need to adjust the timing of incubation recesses to protect eggs when nest sites are too hot to protect embryos, which generally are more tolerant of cold temperatures than even short exposures above 104°F (40°C) ((Wiebe and Martin 1998b, p. 1142;Webb 1987, p.888).

2.4.2 Post-breeding habitat

White-tailed ptarmigan observed in Mount Rainier National Park in post-breeding season (July 31) were in boulder fields near permanent snowbanks; boulders were interspersed with *Carex* (T. Frederick, personal observation). Skagen (1980) did not differentiate between breeding season habitat and post-breeding habitat in her North Cascades study, therefore the following is a repeat of her breeding season information, or surrogate information from other subspecies.

2.4.2.1 Vegetation communities

During July and August (a period including both breeding and post-breeding seasons), Mount Rainier white-tailed ptarmigan were observed in communities of mountain heather (*Phyllodoce empetriformis* and *Cassiope mertensiana*), dwarf huckleberry (*Vaccinium deliciosum*) crowfoot (*Leutkea pectinata*), sedge (*Carex nigricans, C. spectabilis*), and Tolmie's saxifrage (*Saxifraga tolmiei*) (Skagen 1980, p. 2).

In the Sierra Nevada of California, the introduced population of Southern white-tailed ptarmigan selected moist vegetation communities in the *Salix anglorum antiplasta* alliance. At the plant association level, white-tailed ptarmigan in the post-breeding season used the Mertens cassiope-Brewer heather (*Cassiope mertensiana-Phyllodoce breweri*) association most frequently; other associations used included Mt. Dana sedge-little elephant's head (*Carex subnigricans-Pedicularis attollens*), mountain carpet clover-alpine cat's tail (*Trifolium monanthum-Phleum alpinum*), and arctic-alpine snow willow (*Salix nivalis*; (Frederick and Gutierrez 1992, p. 894). On Vancouver Island, white-tailed ptarmigan breeding and post-breeding habitat includes both alpine heather and subalpine heather communities with tree islands of spruce (*Picea* spp) or subalpine fir (*Abies lasiocarpa*) (Martin, unpublished data *in* Martin et al. 2004, p. 239).

2.4.2.2 Water and snow

Post-breeding habitat in the Sierra Nevada is farther from snow than breeding season habitat, but snowmelt provides the moisture that allows for the greater vegetation cover found in sites selected by white-tailed ptarmigan (Frederick and Gutierrez 1992, p. 895). Sites used by white-tailed ptarmigan had greater cover of dwarf willow and soil, and were closer to water than unused sites (Frederick and Gutierrez 1992, p. 895). During the post-breeding season, white-tailed ptarmigan are concentrated in topographic depressions where mesic vegetation cover is greatest. Distance to water was also an important variable predicting white-tailed ptarmigan occurrence on Vancouver Island (Fedy and Martin 2011, p. 311).

In 2011, white-tailed ptarmigan flocks in Glacier National Park, Montana were in close proximity to water and snow, but further than they were in a study done in the same location in the 1990's (Benson and Cummins 2011, p 241). The authors suggest they were further from snow and water to be closer to forage, which had not moved upslope as quickly as receding snowbanks.

2.4.2.3 Boulders/rocks

Boulders and rocks are important for cover and thermoregulation during the post-breeding season. Rocks were used as cover in the North Cascades (Skagen 1980, pp. 17-19). Boulders (rocks greater than 30 cm [12 inches] diameter) are important for hiding and thermal cover; in the Sierra Nevada, flocking birds used sites with more boulders and less turf than brood-rearing areas in step-wise discriminant analysis models (Frederick and Gutierrez 1992, p. 895). The boulder cover provides shade from harsh summer sun, particularly on hot or windy days, and the authors hypothesized this was to reduce thermoregulatory energy demands. Ptarmigan primarily used rock fragments greater than approximately 12 in (30 cm) in diameter and fractured rock shelves (Frederick and Gutierrez 1992, p. 895). Boulder cover was also an important variable in habitat models on Vancouver Island (Fedy and Martin 2011, p. 311). Similarly, in Montana, white-tailed ptarmigan were most often seen in areas having rocks 6-24 inches (15-61 cm) in diameter (Choate 1963, p. 686). Range-wide, white-tailed ptarmigan are adapted to using crevices in rocks for cover, and are associated with rough microterrain on stable substrates (Weeden 1959, p. 120).

In the Rocky Mountains, post-breeding areas usually center on late-lying snow fields, or other moist sites, and are best described as a mosaic of rock fields and low growing vegetation consisting principally of sedges, knotweeds, clovers, and alpine avens (*Carex* spp., *Polygonum* spp., *Trifolium* spp., and *Geum rossii*). Rocks commonly exceed approximately 11.8 in (30 cm) in diameter (rocks this size are referred to as "boulders" in some other white-tailed ptarmigan studies) and comprise over 50 percent of the ground cover (Hoffman 2006, p. 26). Fellfields immediately adjacent to moist alpine meadows and areas of "patterned ground" caused by a process known as cryopedogenesis[4] are important summer use sites for ptarmigan (Hoffman 2006, p. 26).

[4] Cryopedogenesis is the main soil-forming process in soils that are affected by permafrost. Cryopedogenesis includes cryoturbation, which is a collective term used to describe all soil movements that are due to frost action.

2.4.2.4 Topographic position

Topographic position may vary regionally. In the Sierra Nevada, white-tailed ptarmigan moved into less steep topographic depressions following breeding (Frederick and Gutierrez 1992, p. 895), while in the Rocky Mountains, white-tailed ptarmigan move upslope following the conclusion of breeding (Braun 1969, pp. 139-140). Post-breeding areas in the Rocky Mountains are on high, rocky, windswept ridges, benches, and mountain tops above the elevation of breeding territories (Braun 1969, pp. 139-140).

Figure 2. Post-breeding habitat on Mount Rainier. Ptarmigan were observed in shade of boulders near top right of photo. Photo by T. Frederick, July 31, 2018.

2.4.3 Winter habitat

No studies of Mount Rainier white-tailed ptarmigan use of winter habitat have been conducted. We expect that the winter habitat of Mount Rainier white-tailed ptarmigan is different from other areas for a number of reasons. First, Colorado has large areas of extensive, relatively flat riparian valleys with willow shrubs; we do not have similar areas in Washington (M. Schroeder, pers. comm., July 10, 2019). Second, the Cascades have some of the deepest snowpack in North

America. It is likely that willow stands within the range of Mount Rainier white-tailed ptarmigan are buried by winter snows. Third, disturbance by avalanches are frequent. We expect that Mount Rainier white-tailed ptarmigan use wind-swept ridges, avalanche chutes, and other clearings that are protected from deep snow accumulations.

Vegetation communities used by wintering white-tailed ptarmigan on Vancouver Island include primarily the Mountain Hemlock Biogeoclimatic Zone (70 percent of 50 observations in the central and 93 percent of 54 detections in the southern portions of Vancouver Island, respectively; KM in (Martin et al. 2015, Overwinter Habitat Section)). On Vancouver Island, mean elevations of radio-tagged birds in winter were 1,386 m ± 214 m for males and 1,297 m ± 270 m for females (KM *in* Martin et al. 2015). On Vancouver Island they have been found both above and below treeline in alpine bowls, hemlock and cedar forest, clearcuts (rarely), and on unvegetated rocky outcrops and cliffs (Martin *et al.* 2015, Overwinter Habitat Section). Similarly, in southwestern Alberta, wintering white-tailed ptarmigan were found both above and below the treeline in alpine cirques and downslope of the cirques in subalpine and stream courses (Herzog 1980, p. 160).

Most information on winter habitat is from the Rocky Mountains, where wintering white-tailed ptarmigan congregate in sexually segregated flocks in areas with soft snow and willows (Hoffman and Braun 1977, p. 110). Flocks congregate at or above treeline at the upper reaches of drainages where snow accumulates due to wind action; such sites are somewhat protected from prevailing winds and normally contain some microsites with soft snow (Braun et al. 1976. p. 2). They show high site fidelity to winter sites, and studies have indicated about 60 percent of the birds return to the same wintering area (Hoffman and Braun 1977, p. 112). Flocks move downslope, below treeline, when weather conditions are harsh. Areas used include stream bottoms and avalanche paths (Braun et al. 1976, p. 4). In Colorado, wintering areas along streams are frequently narrow, less than about 0.5 mi (1 km) in width, but may be quite extensive in length, up to about 6 mi (10 km); Braun et al. 1976, p. 4). These sites are dominated by willow, although alder (*Alnus*) and birch (*Betula*) are important co- or sub-dominants in localized areas. Shrub height is 5-38 cm above snow (Giesen and Braun 1992, p. 267). The height of willow above snow and canopy cover was higher at ptarmigan feeding sites than at random sites (Giesen and Braun 1992, p. 267).

Male flocks in Colorado winter at slightly higher elevations closer to breeding areas; females and juveniles move to lower elevations at or just above treeline (Braun et al. 1976, p. 4). This allows males to remain close to their breeding territories to give them a competitive advantage in securing breeding space, and reduces competition with females for scarce winter forage (Hoffman 2006, p. 17). Males winter in Krummholz of willow and Engelmann spruce, unless poor snow conditions or snow-covered forage forces both sexes to move below treeline along stream courses (Hoffman and Braun 1977, p. 109). Large concentrations of females winter at lower elevations near treeline where dense, tall stands of willow occur (Hoffman and Braun 1977, p. 114). Females move farther distances and congregate in larger numbers on wintering habitat than males (Hoffman 2006, p. 26). We do not know if Mount Rainier white-tailed ptarmigan exhibit this sexual segregation of winter habitat as found in the Rocky Mountains. Sexes cannot be distinguished in winter, so observational data will not reveal any patterns; only marked birds could be used to determine any sexual segregation.

Dominant vegetation types of wintering areas at or above treeline are typically the willow-sedge (*Salix-Carex*) marsh, hairgrass (*Deschampsia*) meadow, sedge-grass (*Carex-Poa*) wet meadow, and krummholz alternately dominated by willow and dwarf Engelmann spruce (*Picea engelmanni*). In Colorado, willow buds and twigs provide the primary food source for ptarmigan from late fall through early summer (Braun et al. 1976, p. 7). In the Sierra Nevada, white-tailed ptarmigan flocks have been observed in aspen stands, eating aspen buds, in winter on multiple occasions (Padgett 1989, pers. comm.). The presence of willow may have the greatest influence on the distribution of white-tailed ptarmigan during this period (Braun et al. 1976, p. 10; Hoffman et al. 2006, p. 23). Both genders winter in areas dominated or co-dominated by willow (Braun 1971, Braun et al. 1976, Herzog 1980, Giesen and Braun 1992).

The effects of wind on snow deposition and hardness play a critical role in affecting the distribution of ptarmigan on wintering areas (Braun and Schmidt 1971, p. 245). Because of wind action, willow bushes on exposed ridges are usually less than approximately 3.3 ft (1 m) tall and are rarely snow covered. Such areas are consistently used as feeding sites throughout winter. During the day when ptarmigan are not feeding, they seek shelter beneath or on the lee side of dwarf conifers growing along ridges. However, snow on the ridges is often shallow and covered with a hard crust, making conditions unsuitable for night roosting (Braun and Schmidt 1971, p. 245). The birds move at dusk to areas of deeper and softer snow along treeline or in bottoms where they can burrow beneath the surface of the snow (Braun and Schmidt 1971, p. 245). At times, they may use small openings below treeline for roosting at night.

Winter snow depth and quality may impact white-tailed ptarmigan reproductive success and population growth rates. Declines in white-tailed ptarmigan populations have been attributed to the influence of warming winter temperatures on the quality or quantity of winter snow used by ptarmigan for nighttime roosting (Wang et al 2002, p. 85). Clarke and Johnson (1992, entire) found late winter (early breeding season) snow depth in the Sierra Nevada to be negatively associated with breeding success that spring. However, too little snow may also be limiting. Wann (2014, p. 560) found a quadratic relationship between cumulative winter precipitation and survival in Colorado, with survival highest at intermediate values and lowest in high and low precipitation years. Frederick and Gutierrez (1992) suggested that although extensive snow reduces availability of nesting and foraging sites in any given year, several years of low spring snow depth may negatively affect breeding success by reducing productivity of plant forage. One of the highest ranked recruitment models developed using long-term demographic data from Colorado included the North Atlantic Oscillation index with a 2-year time lag (Wann et al. 2014, p. 564).

Based on limited observations and the information from other subspecies, we expect wintering Mount Rainier white-tailed ptarmigan will use alpine areas, and open areas in subalpine parklands and openings created by stream courses, landslides, and avalanches within subalpine forests.

The subalpine meadow-forest mosaic or parkland is extensively developed in the mountains of the Pacific Northwest, perhaps to a greater extent than anywhere else in the world. (Franklin and Dyrness 1988, p.248). Vegetation cover is generally continuous and consists of a mosaic of tree clumps, individual trees, ericaceous dwarf-shrublands, and herbaceous meadows (Raymond et al. 2014, p. 118).

2.5 Historical and Current Range and Distribution

The white-tailed ptarmigan is endemic to alpine areas in western North America and is the only species of ptarmigan whose range extends south of Canada (Aldrich 1963, p. 543; AOU 1998, p. 120; Hoffman 2006, p. 12). The historical range of the Mount Rainier white-tailed ptarmigan likely extended just north of the border of Washington State with British Columbia, Canada, in the Cascade Mountains, then south along the Cascade Range to and including Mount St. Helens and Mount Adams. There are no verified accounts of the Mount Rainier white-tailed ptarmigan in the Olympic Mountains in the northwestern part of Washington State (Hoffman 2006, p. 12; Schroeder 2015, p. 68).

The southern extent of the historical range reached down to Mount Adams and Mount St. Helens. Mount St. Helens is an active volcano, which lost approximately 1,314 ft (about 400 m) of elevation when it erupted in 1980 (Brantley and Myers 1997, p. 2). White-tailed ptarmigan occurred on Mount St. Helens regularly before the eruption. Only three white-tailed ptarmigan have been reported on Mount St. Helens following the eruption, and none have been reported since 1996 (unpublished WDFW research data). Little habitat remains, and is unlikely to be suitable. We therefore conclude the population has been extirpated. It is unlikely that enough habitat will develop on Mount St. Helens to support a white-tailed ptarmigan population in the foreseeable future.

Currently, the southern extent of the range is at Mount Adams. Paleoecologic evidence and measurements of current treeline suggest white-tailed ptarmigan may not have historically inhabited mountainous areas south of Mount St. Helens and Mount Adams (Clarke and Johnson 1990, p. 652). However, mesic alpine vegetation and white-tailed ptarmigan may have occurred in the southern Cascades and into the Sierra Nevada of California in early postglacial times, when temperatures were considerably cooler and alpine regions with mesic vegetation were more extensive (Frederick and Gutierrez, p. 899). Extreme climatic warming during the Hypsithermal limited mesic alpine vegetation and likely eliminated ptarmigan from the Sierra Nevada; ptarmigan did not recolonize once alpine vegetation formed again during the Little Ice Age (Frederick and Gutierrez, p. 899).

Original subspecies range descriptions do not discuss if the Mount Rainier white-tailed ptarmigan occurred in British Columbia, however, there is no break in suitable habitat at the international border. In 1955, a map was published of the range of the five subspecies of white-tailed ptarmigan, showing that Mount Rainier white-tailed ptarmigan occur only in Washington and not in British Columbia (Aldrich and Duvall (1955, p. 13). AOU (1957, p. 135) relies on a 1920 description of the subspecies based on a comparison of specimens taken only from Mount Rainier National Park (MORA); the description considered any ptarmigan occurring in the central or southern alpine portions of Washington to be in the same subspecies(Taylor (1920), p. 147). AOU (1957, p. 135) states that the subspecies is a "…resident on alpine summits in…Washington, from Mount Baker south to Mount Adams and Mount St. Helens…intergrading along the northern boundary of the state with *L. l. leucurus*."

We adopted the AOU 1957 designation of the subspecies for delineating the range of this SSA analysis, but acknowledge the range likely extends slightly further north than the U.S. - Canada border because habitat is contiguous across the border. Mapping of the subspecies border at the international boundary was likely a convenience.

White-tailed ptarmigan can disperse approximately 6-18 mi (10-30 km) across suitable high elevation habitat (Fedy et al. 2008, pp. 1912-1913; Giesen and Braun 1993, pp. 74-76; Martin et al. 2000, pp. 510-514; Martin et al. 2015, Range section). Giesen and Braun (1993, pp. 74-76) recorded dispersal distances were greater for juvenile females than males, with a maximum distance of 30 km recorded. Dispersal distance across low-elevation forested areas is expected to be more limited than dispersal through suitable habitat. Rare cases have been reported of white-tailed ptarmigan dispersing farther: two males transplanted to a new breeding site in Colorado travelled approximately 26.7 and 31 mi (43 and 50 km) respectively back to their capture sites (Martin et al. 2000). A 2000 summary of dispersal information concluded that "Demographic exchange likely occurs between populations of white-tailed ptarmigan within approximately 3.1-6.2 mi (5-10 km) for males and approximately 12.4-18.6 mi (20-30 km) for females" (Martin et al. 2000, p. 514). A successful transplantation of white-tailed ptarmigan to Pike's Peak, an area of apparently suitable but unoccupied habitat approximately 37 mi (about 60 km) from the nearest occupied habitat, suggested this site exceeded normal ptarmigan dispersal distances (Hoffman and Giesen 1983; C. E. Braun, pers. observ. *in* (Martin et al. 2000, p. 514)). The largest distance of low-elevation gaps recorded in the literature were for a translocated population in the Sierra Nevada, where the largest gap of habitat crossed in their southward expansion (i.e., Middle Fork San Joaquin River) was 13.7 km, and the largest gap crossed in their northward expansion (i.e., Carson Pass) was 10-20 km (Frederick and Gutierrez et al 1992, p. 892). No evidence has been found of genetic interchange between populations on Vancouver Island separated by a low elevation gap of approximately 24.7 mi (39.8 km); although no shorter gaps were examined to determine if a shorter distance also was a barrier to genetic interchange (Fedy et al. 2008, p. 1913). Based on the genetic isolation found across the 24.7 mi (39.8 km) distance, and the analysis by Martin, Stacey, and Braun presented above, we expect a low-elevation habitat gap (forested, developed, or agricultural areas without riparian stringers) of approximately 18.6 mi (30 km) would constitute a dispersal barrier that would likely separate the subspecies.

Habitat in the area around Vancouver, British Columbia is fragmented, and it is therefore difficult to accurately measure the width of the habitat gap across the low-elevation Fraser Valley. We expect the very low elevation gap is a significant barrier because it is composed of forests, agriculture, cities, and highways: land use types that white-tailed ptarmigan avoid. We expect the width of this barrier will expand due to climate change, urban growth, and other developments.

Combining sightings, dispersal distance, and occurrence and distribution of suitable alpine/subalpine habitat, we estimate that the range of the species extends into British Columbia, Canada to the Fraser Valley, which comprises the northern limit of the Northwestern Cascade Ranges Ecosection and includes a portion of the Eastern Pacific Ranges Ecosection of the North Cascades Ecoregion (Iachetti et al. 2006, no pagination). Exactly how far north into British Columbia the species' range extends is unknown, but we assume not farther north than approximately Lytton, British Columbia, east of the Fraser River in the Cascade Range.

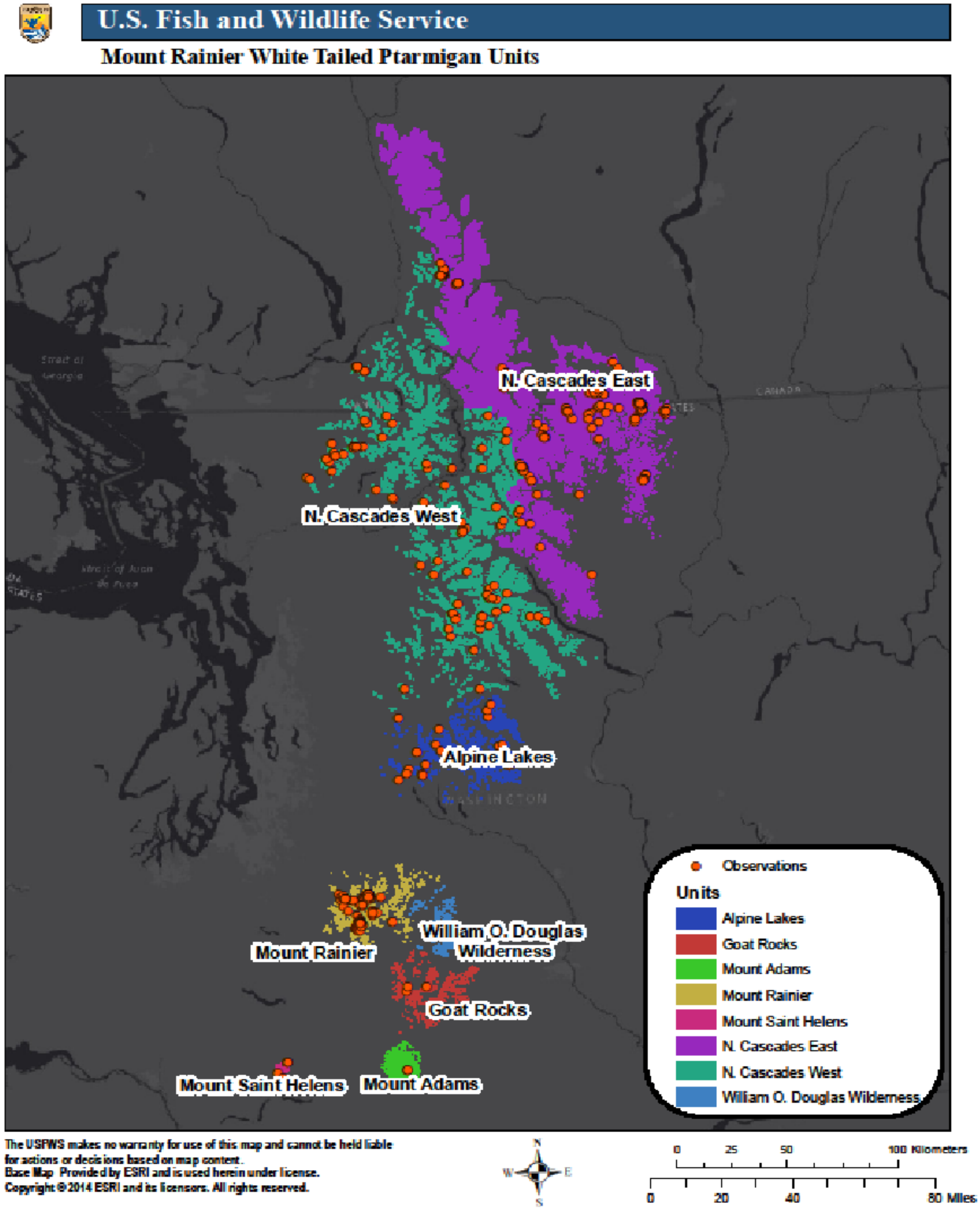


Figure 3. Current distribution of Mount Rainier white-tailed ptarmigan and population units. Maps of each unit are in Appendix C.

2.5.1 Historical and Current Abundance

Densities of Mount Rainier white-tailed ptarmigan are unknown. One study of Mount Rainier white-tailed ptarmigan found densities of 6.25 birds per 100 acres (ac) (approximately 15.44 birds per hectare (ha)) at a site during July and August in the North Cascades (Skagen 1980, p. 4). This estimate is based on one ridge, and only two broods and three males; it includes both the breeding and post-breeding seasons, so is therefore likely to be a high density estimate because densities for white-tailed ptarmigan tend to be higher during the post-breeding season as birds congregate in smaller areas; and in the Sierra Nevada the proportion of habitat occupied decreased from 42 percent in the breeding season to 25 percent in the post-breeding season. (Frederick and Gutierrez 1992, p. 898). During a site visit to Mount Rainier, C. E. Braun observed densities of sites visited in the Washington Cascades appear low relative to Colorado (M. Schroeder, pers. comm. July 2019). Densities have been calculated for other subspecies, but coverage of density estimates across the range of the species is uneven, with most studies occurring in Colorado, Vancouver Island, the Yukon, and the Sierra Nevada of California (introduced population). White-tailed ptarmigan breeding densities fluctuate between years and locations, ranging from about 2.6 to 36 birds per mi^2 (less than 1 to about 14 birds per km^2). Mount Rainier white-tailed ptarmigan populations may or may not be within this wide range reported for other subspecies, and information on densities of each population is needed.

We do not know if there have been changes in abundance of Mount Rainier white-tailed ptarmigan over time. Long-term demographic data from study sites in Colorado show small increases in abundance at one site over time, but contemporaneous sharp declines at another site (Wann 2017, pp. 93-94), indicating strong site to site differences that preclude us from using density data from other regions. The noted declines in Colorado were attributed to loss of willow forage due to elk browsing (Braun et al. 1991, p. 82), and the influence of warming winter temperatures on the quality or quantity of winter snow used by ptarmigan for nighttime roosting (Braun et al. 1976, p. 7; Wang et al 2002, p. 85). Survival of breeding age birds may have a greater impact on the growth of a population than fecundity, though juvenile and adult survival are both important (Wann 2017, pp. 130, 134). We do not know if similar patterns exist for Mount Rainier white-tailed ptarmigan, and suggest these factors related to declines in other areas be investigated for each population of Mount Rainier white-tailed ptarmigan.

We reviewed all available literature for occurrence data of Mount Rainier white-tailed ptarmigan. We obtained databases from the Washington Department of Fish and Wildlife (WDFW), the U.S. Forest Service (USFS), and National Park Service (NPS). We also obtained observations from reliable observers, including professional and retired professional wildlife biologists with experience identifying grouse. We contacted the British Columbia Conservation Data Centre (CDC) and obtained breeding bird atlas data (Martell 2015, entire), but found no white-tailed ptarmigan records within the area close to the international border. The British Columbia CDC does not have any records for white-tailed ptarmigan from any sources in the area, except for eBird, which is the data source we used for Canada. The WDFW research database included eBird observations screened for reliability using a number of factors such as location, photos, and descriptions (M. Schroeder, pers. comm.). The WDFW excluded many observations that were reported in subalpine forests, and were likely to be sooty grouse (M. Schroeder 2019, pers. comm.). We did not consider any observations below approximately 5,250 ft (1,600 m) in elevation to be reliable unless the observation was in winter, photos were provided, and we judged the location was likely to be accurate.

We compiled all available species occurrence data from the above sources and created a geographic information system (GIS) database. Where point data were available, they were included in the database. Where point data were not available (*e.g.*, museum records with general locations), we did not map the occurrence.

Table 2. Mount Rainier white-tailed ptarmigan observations in population units used for analysis.

Representation Unit	Population Unit	Number of Observations
North	Alpine Lakes	98
North	North Cascades West	315
North	North Cascades East	484
South	Mount Adams	2
South	Goat Rocks	4
South	Mount Rainier	289
South	William O. Douglas	0

2.5.2 Land Ownership

Across the range of the species in both countries, the majority of land is in public land management. , and most land within the U.S. portion of the range of the Mount Rainier white-tailed ptarmigan is within federally owned land (76 percent, Table 3).

Table 3. Area in each population unit used for analysis in this SSA.

In b Hectares (acres)	Population Unit	Alpine Lakes	Goat Rocks	Mount Adams	Mount Rainier	North Cascades East	North Cascades West	William O. Douglas	Total	Percent Ownership
Federal	**U.S Forest Service**	132,101 (326,429)	34,808 (86,012)	14,103 (34,849)	35,975 (88,897)	354,435 (875,827)	366,821 (906,435)	25,070 (61,949)	963,313 (2,380,397)	**59%**
	National Park Service	0	0	0	55,917 (138,174)	18,860 (46,604)	139,639 (345,056)	0	214,417 (529,835)	**13%**
	Other Federal	275 (680)	0	0	0	402 (993)	0	0	677 (1,673)	**0.04%**
State		161 (398)	8,522 (21,058)	0	0	24,396 (60,283)	2,576 (6,364)	29 (71)	35,682 (88,173)	**2%**
Tribal		0	17,940 (44,331)	8,087 (19,983)	0	0	0	0	26,027 (64,314)	**2%**
Private/ Other		876 (2,166)	3,488 (8,619)	1,248 (3,084)	360 (889)	141 (348)	1,562 (3,860)	0	7,676 (18,969)	**0.5%**
British Columbia	**Provincial Parks**	0	0	0	0	60,479 (149,448)	39,596 (97,845)	0	100,076 (247,292)	**6%**
	Private/ Other	0	0	0	0	188,077 (464,748)	95,801 (236,730)	0	283,878 (701,477)	**17%**

	Total	133,414 (329,672)	64,758 (160,020)	23,438 (57,916)	92,252 (227,960)	646,788 (1,598,250)	645,995 (1,596,289)	25,100 (62,022)	1,631,746 (4,032,129)	

3.0 SPECIES ECOLOGICAL NEEDS

3.1 Individual Resource Needs

In this section, we describe the needs of Mount Rainier white-tailed ptarmigan at the individual level. Using the known life history characteristics of white-tailed ptarmigan described above, we identified the specific ecological needs for individuals to survive and reproduce (Table 2). We developed the list of individual needs primarily on research conducted on other subspecies of white-tailed ptarmigan as a surrogate for the Mount Rainier white-tailed ptarmigan. These needs vary between seasons as white-tailed ptarmigan establish territories in snow-free patches in the spring, find suitable nest sites and raise broods, move upslope into post-breeding areas and establish flocks, then move downslope to wintering areas. In our description of individual needs, we have lumped the seasons into three key stages: 1) breeding, including territory establishment, nesting, and early brood-rearing; 2) post-breeding, including the late summer and fall when white-tailed ptarmigan move to areas that are higher in elevation with more boulder cover; and, 3) winter, which generally occurs from late October to Early May. In each of these seasons, individuals need a suitable microclimate and adequate amounts of quality forage.

A suitable microclimate is important for this cold-adapted bird. Their low thermal neutral zone, slow metabolic rate, low evaporative cooling efficiency, and abundance of adaptations to cold result in a high ability to tolerate cold stress and a low ability to tolerate heat stress. In the breeding season, heat stress is unlikely in early spring, but will increase as hens are restricted to static nesting sites and temperatures increase as the season progresses. Hens are required to remain stationary on nests most of the day and are exposed to high temperatures and solar radiation.

Adults are likely limited by warm temperatures and solar radiation. White-tailed ptarmigan will pant at temperatures above 21 degrees C (70 degrees F) and have the lowest evaporative cooling efficiency of any bird (Johnson 1968, entire). Thermal behavioral adaptations include seeking cool microsites such as shade and snowbanks; the absence of these microsites may preclude presence of the species (Johnson 1968, p. 1012). Locations chosen by ptarmigan tend to have lower average high temperatures than random areas nearby (Benson and Cummins 2011, p. 242). Therefore, we expect any adult white-tailed ptarmigan exposed to temperatures above 21 degrees C (70 degrees F) are likely to expend additional energy on thermoregulation. However, this 21 degree C (70 degrees F) limit for adults does not directly translate to ambient air temperatures, as temperatures may be cooler in microsites with shade, near water, or near snowbanks or glaciers. We do not know the relationship between average ambient air temperatures measured over a large area and the availability of cool microsites suitable for white-tailed ptarmigan, but expect that microsites will become more important as ambient temperature increases. Areas with complex topography, large boulders, and well-distributed snowbanks and streams are more likely to have an abundance of microsites with suitable microclimates. Some microsites may become ineffective as air temperatures increase.

In the post-breeding season, temperatures become warmer, air is drier, and the effects of heat stress become more likely. During this period, white-tailed ptarmigan move to boulder fields near moist depressions. Access to snow is limited due to snowbank recession upslope and fragmentation of snow fields. Ptarmigan further from snow are unable to utilize the cooling winds and temperatures near snowbanks. With less access to snow, boulder cover becomes more important. Ambient temperatures are high, and solar radiation is greater at higher elevations.

In Washington, winter temperatures are warm in comparison to those in other parts of the range of the species (Appendix A). Based on temperature alone, cold stress appears unlikely within the range of Mount Rainier white-tailed ptarmigan, with the possible exception of the areas east of the Cascade Crest. However, snow conditions are different from those encountered by other white-tailed ptarmigan subspecies, as snow tends to be deep, wet, and heavy west of the Cascade crest. The deepest snow records in the U.S. have included both the North Cascades National Park, and Mount Rainier (NPS 2019). These snow conditions may limit the availability of roost sites as snow in the Cascades often develops a hard surface crust, which make digging a snow roost difficult (Braun et al. 1976, p. 3). Additionally, wet, heavy snow has less insulative value. Therefore, suitable microclimates for snow roosts in winter in western Washington may be a limiting factor, despite the moderate, warmer winters. Pika (*Ochotono princeps*) in the North Cascades, are similar to ptarmigan in their need for snow for winter insulation. Pika are subniveal in winter (living under the snow); lack of snow exposes them to low winter temperatures, and has been related to reduced pika abundance in the North Cascades (Johnston et al. 2019, entire).

Adequate amounts of forage are essential for survival and reproduction. As described in the life history and diet sections, above, white-tailed ptarmigan have different forage requirements based on age, season, and geographic region. We have no information on the forage requirements of Mount Rainier white-tailed ptarmigan in winter. Based on very limited diet analysis and studies from other parts of the range of the species, we expect they forage on willow, alder, and birch. Willow is less prevalent in Washington than Colorado, so we expect alder and birch comprise a large part of the winter diet. These shrub species are found in riparian areas, avalanche chutes, windswept ridges, and clearings created by fire or clearcuts. However, we have no information to determine if the deep snow characteristic of the Cascade Range buries shrubs in these areas, and therefore limits access to forage.

During the breeding season, we expect Mount Rainier white-tailed ptarmigan will forage in vegetation communities similar to those reported in other areas, and on similar forb species. We also expect they will use moist low-statured vegetation close to snow and/or water, and use boulders for cover. We expect vegetation communities used by Mount Rainier white-tailed ptarmigan are alpine communities that contain ericaceous subshrubs, graminoids (particularly *Carex* species), and dwarf willows (*Salix* spp less than about 10 cm in height). Our expectations for the most important habitat needs for individuals are summarized below in Table 4.

Table 4. The ecological requisites for survival and reproductive success of Mount Rainier white-tailed ptarmigan individuals.

Season	Individual "Need"	Source(s) and location of source studies
Breeding	Dwarf willow	Sierra Nevada, California: (Frederick and Gutierrez 1992, p. 895; Clarke and Johnson 2005, entire).
	Forb/Graminoid cover	Sierra Nevada, California (Frederick and Gutierrez 1992, p. 895); Vancouver Island, British Columbia (Fedy and Martin 2011, p. 311); Colorado (Spear 2020, p. 178).
	Ericaceous subshrubs	North Cascades, Washington: (Skagen 1980, p. 4)
	Moist forage	Sierra Nevada, California (Frederick and Gutierrez 1992, p. 895)
	Appropriate timing of forage	Colorado (Wann 2017, entire; Wann et al. 2019, entire);
	Proximity to water	Sierra Nevada, California (Frederick and Gutierrez 1992, p. 895); Vancouver Island, British Columbia (Fedy and Martin 2011, p. 311)
	Boulder cover	Sierra Nevada, California (Frederick and Gutierrez 1992, p. 895); Vancouver Island, British Columbia (Fedy and Martin 2011, p. 311); Colorado (Spear 2020, p. 178).
	Thermal refugia	Glacier National Park, Montana: (Benson and Cummins 2011)
	Nests sites with suitable cover and microclimate	Mount Evans, Colorado (Wiebe and Martin 1998b, p. 1143)
	Ambient temperatures <21°C (70°F)	All subspecies (Johnson 1968, p. 1012)
	Insects for chicks	All subspecies (May 1975, p. 28)
Post-breeding	Dwarf willow cover	Sierra Nevada, California: (Frederick and Gutierrez 1992, p. 895; Clarke and Johnson 2005, entire).
	Forb/Graminoid cover	Sierra Nevada, California: (Frederick and Gutierrez 1992, p. 895).
	Ericaceous subshrubs	North Cascades (Skagen 1980, p. 4); Sierra Nevada, California (Frederick and Gutierrez 1992, p. 895) Vancouver Island, British Columbia (Fedy and Martin 2011, p. 311)
	Moist forage	Skagen 1980, Vancouver Island (Fedy and Martin 2011); Sierra Nevada (Frederick and Gutierrez 1992

Season	Individual "Need"	Source(s) and location of source studies
	Boulder or rock cover/ thermal refugia	Montana (Benson and Cummins 2011); Sierra Nevada, California (Frederick and Gutierrez 1992, p. 895); Vancouver Island, British Columbia (Fedy and Martin 2011, p. 311); Colorado (Spear 2020, p. 178).
	Ambient temperatures <21°C (70°F)	All subspecies (Johnson 1968, p. 1012)
	Basins above treeline	Colorado (Braun et al. 1976, entire)
Winter	Avalanche chutes and stream bottoms below treeline	Colorado (Braun et al. 1976, p. 4) (Schroeder 2019, pers. comm)
	Willow, alder, and birch	(Braun et al. 1976, p. 4)
	Mosaic of snow depths such that shrub buds are available 5-38 cm above snow, and snow deep enough for roosting is also available nearby.	(Braun et al. 1976, p. 7; Giesen and Braun 1992, p. 267)
	Snow quality and depth suitable for roosting	(Braun et al. 1976, p. 7)
	Access to Grit	Colorado (Braun 2019, pers. comm.); (May and Braun 1972, p. 1181; (May and Braun 1973, p. 56).

3.2 Population Needs for Resiliency

In this section, we describe the needs of Mount Rainier white-tailed ptarmigan at the population level. These needs are subdivided into demographic factors and habitat factors. We adopted the condition category rating system used for viability assessment in The Nature Conservancy's Conservation Action Planning framework (The Nature Conservancy 2010), used to implement the Open Standards for the Practice of Conservation (Conservation Measures Partnership 2013, entire). Thus, each population need was considered a "Key ecological attribute." We assigned each key ecological attribute one or more measurable indicators. We created condition categories of Poor, Fair, Good, or Very Good to each indicator, based on what we consider an acceptable range of variation for the indicator, and the need for human intervention to maintain the attribute. These categories do not imply this SSA is making judgment on whether or not the species warrants listing and needs recovery. Table 5 below summarizes the categories:

Table 5. Description of each rating category for indicators of species needs. Rating categories are adapted from the Open Standards for the Practice of Conservation (Conservation Measures Partnership 2013, entire).

Value Ranges	Definition (definitions adapted from Conservation Measures Partnership 2013)
Poor:	Restoration of the key attribute is increasingly difficult. May result in loss of the local population
Fair	Outside acceptable range of variation; Requires human intervention. This level would be associated with a decreasing population.
Good	Indicator w/in acceptable range of variation; Some intervention required for maintenance. This level would be associated with a stable population.
Very Good	Ecologically desirable status; Requires little intervention for maintenance. This level would be associated with a growing population.

3.2.1 Demographic needs

Here we describe those attributes we consider "key" to population stability. In general, healthy demography is a function of population size (N) and its population growth rate (lambda, λ). Lambda is a function of reproductive capacity and survival rates of individuals of various age classes. For a population to be growing, λ must be >1. The size of a population influences population viability through the processes of demographic and environmental stochasticity.

No population ecology or viability studies of the Mount Rainier white-tailed ptarmigan have been conducted. One density estimate for one small area was reported (6.25 birds per 100 ac (approximately 15.44 birds per ha)) (Skagen 1980, p. 4), but this estimate appears inflated (Braun 2019, pers. comm; Hoffman 2020 pers. comm; Wann 2020 pers. comm). No studies reporting population size, age and sex ratios, growth rates, or other demographic rates have been conducted on Mount Rainier white-tailed ptarmigan. To identify population needs for the Mount Rainier white-tailed ptarmigan we rely on studies from other subspecies of white-tailed ptarmigan. Genetically, Mount Rainier white-tailed ptarmigan are most similar to northern white-tailed ptarmigan (mainland Canada; Langin et al. 2018, entire), but most studies have been conducted on southern white-tailed ptarmigan (Colorado) and Vancouver Island white-tailed ptarmigan (Vancouver Island), and some limited demographic estimates are available for the introduced population of Southern white-tailed ptarmigan (18 years after release) in the Sierra Nevada, California. Population ecology studies from Colorado indicate stable populations of white-tailed ptarmigan have high adult survival rates (Wann et al. 2017).

Because these Colorado populations are stable, we consider the demographic attributes exhibited by these populations to be within an acceptable range of variation but it is important to note that the indicators in Table 6 may or may not accurately reflect the demographic requirements for resiliency of ptarmigan populations in the Cascades. The information presented for demographic needs in Table 6 are meant to demonstrate minimum demographic data that needs to be collected for Mount Rainier white-tailed ptarmigan. Subsequent analysis and modelling may determine needs are different from those of the surrogate populations used to construct the table (e.g. recruitment may be more important than adult survival).

Table 6. Demographic needs of populations of white-tailed ptarmigan, measurable indicators, and condition rating descriptions.

Demographic Need	Indicator	Poor	Fair	Good	Very Good	Source
Population structure & recruitment	Annual adult survival		<50 percent	50-75 percent	> 75 percent	Braun 1969 (Thesis) "annual turnover of 45%" in CO; Hannon and Martin 2006, p. 426 = adult survivorship was 0.77; Wilson and Martin 2011, p. 466, Annual survival of females was 0.35-0.44, while ann. surv. of males was 0.48-0.59.
Population structure & recruitment	Nest success	< 30 percent	31 percent to 60 percent	61 percent to 75 percent	> 75 percent	Martin and Wilson 2011, p. 47 (0.4-2.04 female fledglings per female, citing Sandercock 2005 and Wilson & Martin 2011 (p. 465-6: daily nest survival of 0.952-0.971 depending on location, with mean annual nest success of 0.24-0.40); Braun and Rogers 1971, p. 42, nest success was 25%-75% in CO; Clarke and Johnson 1992, p. 624 - least amount of snow yields highest nest success of 61%, while most snow yields 2nd lowest nest success of 25%. Breeding success is correlated to snow depth with 15% nest success in deep snow, and 80% when there's little snow. The negative effect of snow maxes out at 200 cm depth.; Wann 2017, p. 39 showed ~56% nest success (defined as "one or more eggs hatched"); Braun 1969, p. 61 - nest success during 1966-68 varied from 27% to 75% at three sites, Braun IDs 27% and 30% as Poor and 50% as Fair.
Population size & dynamics	Number of breeding pairs per population					A population viability analysis (PVA) is needed to determine the size needed. The category of Fair would be indicated by a minimum PVA.

Demographic Need	Indicator	Poor	Fair	Good	Very Good	Source
Population size & dynamics	population growth (lambda)	<1	1	>1	>1	Population growth rate must be stable or increasing for viability.

3.2.2 Habitat needs

Habitat use across the range of white-tailed ptarmigan is discussed in the Habitat section, above. Here we describe those attributes we consider “key” to survival and reproduction, that is, those habitat elements that if removed or destroyed would likely cause extirpation of a population. We developed the value ranges for each categorical ranking using the same definitions as for demographic needs, above. Indicators are not necessarily the best potential measure of each key attribute, but represent the best currently available measure. For example, although length of exposure to elevated temperatures (above 21 degrees C) is the best measure of physiological stress due to heat, the available measures for future projections are days above 30 degrees C and maximum summer temperatures, which are likely correlated with exposure to temperatures above 21 degrees C, and are therefore our best available indices of exposure to elevated temperatures.

Table 7. Habitat needs of Mount Rainier white-tailed ptarmigan, measurable indicators, and condition rating descriptions.

Population Need	Indicator	Poor	Fair	Good	Very Good	Ratings Source
Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	small gaps with frequent connections	contiguous	
Cool ambient temperatures in summer	Maximum summer temperature	>38 degrees C (100 degrees F)	21.1-38 degrees C (70.1 degrees F - 100F)	**13.4-21 degrees C (56 -70 degrees F)**	7.3-13.3 degrees C (45 – 56 degrees F)	Pant at 21 degrees C. (Johnson 1968, p. 1012), and thermal neutral zone tops out at 38 degrees C (Johnson 1968). Mean July temp was the main meso- (1 km^2) and macro-scale (100 km^2) predictor for rock ptarmigan (Revermann et al. 2012). Indicates the scale of this variable could potentially be useful for white-tailed ptarmigan too.
Cool ambient temperatures in summer	Number of days above 30 degrees C	>3	1 to 3	0-1	**0**	Pant at 21 degrees C. (Johnson 1968, p. 1012), and thermal neutral zone tops out at 38 degrees C (Johnson 1968). Although the best measure of ptarmigan exposure to heat would be the amount of time they are exposed to temperatures above 21 degrees, we are using the available data for current and projected temperatures as an index. This indicator is likely to be correlated with the amount of time white-tailed ptarmigan habitat is above 21 degrees. We would really want 0 days above 21 degrees C for VG, because under those conditions they could freely forage all day and incubate on open nests without any physiological costs. Using 0 days for 30 degrees C for Good, because that may mean some days above 20 degrees C, but all shaded areas are < 20 degrees.

Population Need	Indicator	Poor	Fair	Good	Very Good	Ratings Source
Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	<0.5	0.5 to 0.75	> 0.75 to 1	**>1**	Glacier melt has been modelled by Frans et al. (2018) for basins in the North Cascades and Rainier population units. We are using this data to inform our ratings for those units. Ratings are extrapolated from their results by Glacier Class Adams (Class 4) Goat Rocks (Class 3) Rainier (Class 4) Alpine Lakes (Class 1 and 4) North Cascades West (Classes 1,2,4) North Cascades East (Class 3)
Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalent (April 1)	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	Snow water equivalent measures the amount of water available in the snow. This will indicate how much moisture will be available to snowbeds and other vegetation downslope of the snow banks.
Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy	Snow needs to be suitable for roosting - hard surface crust would prevent creating the roost, and snow that is too wet would not provide good insulation. (Braun et al. 1976, p. 7; Braun and Schmidt 1971, p. 245)
Winter snow	Winter snow depth	too deep or too shallow	too deep or too shallow	slightly too deep or too shallow, but within historical range of variation	Within optimum range of variation	Many depths reported in other areas (for other subspecies), but depths in Washington and B.C. expected to be different. What is important to white-tailed ptarmigan is access to shrubs (height above snow) and suitability of snow for roosting.
Spring snow cover	Area of breeding habitat covered in snow at start of breeding season.					Clarke and Johnson (1992, entire) and Martin and Wiebe (2004). Too much snow limits the availability of habitat for breeding territories. Absolute values for determining the categories are not available.
Abundance of food resources	area of willow, alder or birch (winter)					

Population Need	Indicator	Poor	Fair	Good	Very Good	Ratings Source
Abundance of food resources	Distance to water during breeding season	>200 m	61-200 m	11-60 m	<10 m	Distance to water important (Fedy and Martin 2011, pp 311, 313; Frederick and Gutierrez 1992, p. 895). Latter found highly selected feature, with used plots 8.1m (+/- 1.77 m) to water and unused 53.5m (Table 3). Good and VG based on Frederick and Gutierrez, Fair and Poor (upper ends of range) based on Fedy and Martin
Abundance of food resources	NDVI [5](early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann	
Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch	Based on information from Wann (2019, entire).
Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	Historical means and Standard Deviation (SD) are based on U.S. Geological Survey (USGS) Climate Wizard data for each population unit. Historical range of variation supported Mount Rainier white-tailed ptarmigan over time.
Abundance of food resources	Width of unvegetated area of glacial forefront (not colonized by forage plants yet)	Areas > 300 m across	Areas 200-300 m across	Areas 100-199 m across	Areas < 100 m across	Based on territory size of white-tailed ptarmigan calculated from densities reported for other subspecies.
Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	20-22% cover	**22-26% cover**	Range of cover for used sites = 22-26% (Frederick and Gutierrez 1992, p. 895); ranged from 5-45 % cover on Vancouver Island (Fedy and Martin 2011, p. 312).
Cool microclimates	Glacial equilibrium line altitude		>300 m above 1993-2018	<=300 m above 1993-		Glaciers and snowbanks have cool air emanating from them. Proximity of glaciers to ptarmigan habitat can be measured by

[6] Ratings for the categories of landscape context, condition, and size reflect the lowest ratings of the individual "needs" in each category; and the overall resiliency rating for each population unit are the average of scores for the categories of landscape context, condition, and size.

Population Need	Indicator	Poor	Fair	Good	Very Good	Ratings Source
			mean levels	2018 mean levels		glacial equilibrium altitude (ELA). North Cascades glaciers have varied 200- 300m in this altitude between 1993 and 2018 (J. Riedell, pers. comm.) Snowline may be lower or higher than ELA, but ELA is a good index for evaluating change over time. Glacial ELA for North Cascades: For Noisy Glacier P.O.R. (1993-2018) ELA is 1,838 m, Silver Glacier 2,369 m, Sandalee Glacier 2205m, and North Klawatti Glacier 2,175 m. These data show the ELA is higher east of the Cascade crest.
Total area of modelled summer habitat	hectares of alpine vegetation modelled from Transboundary Project		<4,000 ac	4,000 ac or more		The smallest continuously occupied areas in New Mexico are 3,475 acres. We rounded up because although populations are persisting in this area, there may be a gradual declining trend undetected. Habitat that appears suitable for ptarmigan in the Snowy Range (where they are presumed extirpated) encompasses <10 km2 (2470 ac) with poor connectivity (approximately 50–80 km) to occupied habitats in Colorado (Braun and Wann 2017, p. 309).
Total area of summer habitat	hectares of "alpine" vegetation		<4,000 ac	4,000 ac or more		Smallest size of continuously occupied areas in New Mexico.
Total area of winter habitat	hectares of avalanche and other openings in subalpine		2-7 km^2	**8-100 km^2**	> 100 km^2	

3.3 Species Needs for Redundancy & Representation

The ability of a species to persist in the face of catastrophic events is reflected in sufficient number and distribution of large, stable, and connected (resilient) populations. Redundancy spreads risk among multiple populations or across areas to minimize the risk due to large-scale, igh-impact (i.e., catastrophic) events (Smith *et al*. 2018, p. 306). We can assume therefore that many populations distributed throughout the range of a species (redundancy), and within its dispersal distance, would provide for more secure populations than would fewer populations restricted to only certain areas of the range (Hanski 1982, entire). Catastrophic events that could reasonably occur within the range of Mount Rainier white-tailed ptarmigan could include eruption of one of the volcanoes. Eruption of Mount St. Helens in 1980 caused the extirpation of one population and a loss of redundancy for the species.

The ability of the species to adapt to physical (e.g., climate conditions, habitat conditions or structure across large areas) and biological (e.g., novel diseases, pathogens, predators) changes in its environment presently and into the future is its adaptive capacity; it is the evolutionary capacity or flexibility of the species. Representation is the range of variation found in a species, and this variation--called adaptive diversity--is the source of species' adaptive capabilities. Genetic diversity is the primary fuel for adapting to changing environmental conditions (Hendry *et al.* 2011, pp. 164-165); for adaptation to occur there must be variation upon which to act (Lankau *et al.* 2011, p. 320). Gene flow is influenced by the degree of connectivity and landscape permeability (Lankau *et al*. 2011, p. 320). To preserve the breadth of genetic diversity, it is important to maintain high levels of gene flow among populations. Phenotypic diversity (the physiological, ecological, and behavioral variation expressed by a species) is also important for adapting to changes in environmental conditions. Phenotypic variation determines how organisms interact with their environment and how they respond to selection pressures (Hendry *et al.* 2011, p. 161). The degree of phenotypic variation is determined by the diversity of physical and biological pressures to which organisms are exposed, which vary across spatial and temporal scales. As such, species that span environmental gradients are expected to harbor the most phenotypic and genetic variation (Lankau *et al.* 2011, p. 320).

To sustain viability and be resilient to threats, the Mount Rainier white-tailed ptarmigan needs multiple resilient populations that represent a range of ecological and genetic diversity across its range. To achieve this goal, the species must occur in multiple populations within each region. We estimate the need for three populations within each representation unit so that there is redundancy even if one population is lost due to a natural disaster, such as volcanic eruption. The separate regions are needed to allow for possible genetic, phenotypic, and ecological differences among the regions.

Table 8. Summary table of the species level needs of Mount Rainier white-tailed ptarmigan.

3Rs	Needs for long-term-viability	Description
Resiliency	Habitat that provides for sufficient levels of survival, recruitment, and interconnectedness to support stable or increasing populations.	Demographic and habitat attributes ("needs") that describe resiliency of each population are described in detail in Tables 2 and 3. We used the quality and quantity of habitat as our basis for resiliency analysis of current and future conditions. We define a resilient population as one with large areas of interconnected breeding, post-breeding, and winter habitat (totaling at least 4,000 acres per population) with the following qualities: 1) Breeding season habitat with large patches of low-statured alpine vegetation with moist forbs, insects, and boulder cover. Snow and water are in close proximity; 2) Post-breeding habitat with moist depressions of low-statured vegetation and boulder cover; and 3) Winter habitat of alpine areas; and riparian areas, avalanche chutes, and other openings in the subalpine zone. These areas have willow, alder, or birch exposed at appropriate heights for foraging white-tailed ptarmigan, and have areas with accumulation of fluffy snow for snow roosts. Each population must be large enough to be stable or increasing over time.
Representation	Maintain diversity	Not enough information to understand species needs for representation at present. The North and South Units provide representation in different ecological regions. Maintaining resilient populations in each unit would maintain occupancy across the broad and diverse region occupied by the species.
Redundancy	Sufficient number of large, healthy, resilient populations.	Three resilient (as defined above) populations within each representation region to buffer against catastrophic losses.

4.0 FACTORS INFLUENCING THE SPECIES

4.1 Factors considered but not carried forward

Individual survival and reproduction could be influenced by disease and mortality from certain anthropogenic causes, although these have not been investigated for white-tailed ptarmigan. One potential cause of mortality is collision with ski lifts, which have been associated with rock ptarmigan deaths in Scotland, Norway, and France (Imperio et al. 2013, pp. 7-8). Developed ski areas within the range of Mount Rainier white-tailed ptarmigan include Mount Baker (North Cascades West population unit), Stevens Pass (in the Alpine Lakes population unit), Crystal Mountain (Mount Rainier population unit), and White Pass (Goat Rocks population unit). We do not have enough information on the location of wintering Mount Rainier white-tailed ptarmigan to evaluate the likelihood of exposure to these ski lifts. However, we expect exposure is low, considering the small number of ski areas within the range of the species.

Future development of infrastructure is not expected in alpine areas of Washington, with the exception of helicopter landings, which are small in area. Loss of breeding season or post-breeding season habitat from infrastructure development, mining, or grazing is not expected to occur over an appreciable area. No recreational developments are planned on the Okanagan National Forest (Kuk 2019, pers. comm.), Mount Rainier National Park (Chestnut 2019 pers. comm.), or the North Cascades National Park (Ransom 2019, pers. comm.). The effects of any historical mining are unknown, but current and future mining is unlikely on most areas due to the limited access and restrictions; most of the Pasayten Wilderness is administratively withdrawn from mining (Kuk 2019, pers. comm.). Historical grazing may affect current habitat quality, but we do not know the severity or scope of the impacts and grazing does not occur in the alpine meadows of each population unit, except for pack stock along trails. We also do not know if mountain goat populations are negatively influencing breeding or post-breeding habitat, but mountain goat populations are declining statewide, particularly in the North Cascades population units, and appear to be stable in the Mount Rainier, Goat Rocks and Mount Adams population units (Rice 2012, entire).

We have considerable uncertainty about the potential for complete loss of populations from catastrophic events during the next century. Five volcanoes are in the range of the subspecies (from north to south these are Baker, Glacier Peak, Rainier, St. Helens, and Adams). Geologists predict "eruption is certain," but the timing is unknown (USGS 2019). Historically, Cascades Mountains (Washington, Oregon, and California) volcanoes erupted at a rate of one to two per century (USGS 2019). The Mount St. Helens population unit of Mount Rainier white-tailed ptarmigan was lost to a volcanic eruption in 1980, but previous Cascades Mountains eruptions in Washington were more than 1,000 years ago (USGS 2014, 2015, 2017a and b, 2018a).

Other types of volcanic events that are not strictly termed as "eruptions" have occurred more recently. These included events such as lava flows, pyroclastic flows (avalanches of hot rock and volcanic gases), volcanic ash or debris fall (a.k.a. tephra), debris avalanches, ballistic ejecta, rock falls, and lahars (mudflows). At Mount Baker, future hazards include lava flows, pyroclastic flows, tephra falls, lahars, and flank failures (USGS 2013c). Its threat potential is considered by USGS to be "very high" (USGS 2017a). At Glacier Peak, future hazards include tephra falls, pyroclastic flows, and lahars (USGS 2013a). Its threat potential is determined by USGS to be "very high" (USGS 2015). At Mount Rainier, considered by USGS to be the most threatening of the Cascades volcanoes, future hazards include volcanic ash, lava flows, and pyroclastic flows (USGS 2016). Its threat potential is determined by USGS to be "very high" (USGS 2018b). At Mount St. Helens, the greatest hazards are from resumption of lava-dome growth, tephra falls, lava flows, pyroclastic flows and large lahars (USGS 2013d). Its threat potential is determined by USGS to be "very high" (USGS 2017b). At Mount Adams, the greatest hazard is from landslides, debris avalanches, and lahars (USGS 2013b). Its threat potential is determined by USGS to be "high" (USGS 2018a). Although it seems likely a volcanic event will cause catastrophic losses or significant reductions of one or more Mount Rainier white-tailed ptarmigan population, we have no way of predicting if this will occur during our analysis timeframe and have not tried to project their likelihood. However, we have considered the potential when setting goals for redundancy.

4.2 Factors carried forward: Stressors and Sources of Stress

We evaluated the scope and severity of each stressor, and the contribution and irreversibility of each source of stress. The result is an overall magnitude score for each stressor. For those indicators which we have future projections under the different climate scenarios, we used the projected measurements to assign a condition category to the indicator. Some attributes are influenced by factors which we could only evaluate qualitatively, such as habitat damage due to increased recreation. For these indicators, we evaluated the likely scope and severity of the stressor.

4.2.1 General models and studies describing relationships to climate change

A number of models and analyses have predicted increased risk to other subspecies of white-tailed ptarmigan as a result of climate change. Vancouver Island white-tailed ptarmigan habitat was modelled by developing ptarmigan distribution models and projecting the effects of climate change on bioclimatic and vegetation elements most associated with ptarmigan presence (Jackson et al. 2015, entire). This climate envelope model predicted large losses of Vancouver Island white-tailed ptarmigan habitat (approximately 201 mi^2 to 88.4 mi^2 (521 km^2 to 229 km^2) under RCP 4.5, and approximately 50.9 mi^2 (132 km^2) under RCP 8.5; Jackson et al. 2015, p. 9). Remaining patches are predicted to be small and fragmented, and unlikely to support the species into the future (Jackson et al 2015, p. 13).

The WDFW has evaluated climate sensitivity of all Species of Greatest Conservation Need. Based on a literature review, they calculated an Exposure Rank based on exposure to climate changes (e.g., temperature and precipitation), climate-driven changes, and disturbance regimes (e.g., water chemistry, altered fire regimes, altered flow regimes), and a Sensitivity Rank based on physiology, phenology, and ecological relationships, A composite rank, Vulnerability, was derived from Exposure and Sensitivity Ranks using the formula: Vulnerability = (Climate Exposure Rank + Sensitivity Rank) ÷ by two (WDFW 2015, pp. 5-1 to 5-5). The WDFW determined that Vulnerability, Sensitivity Rank, and Exposure Rank for white-tailed ptarmigan are each "high", and Overall Confidence in the rankings is "high" WDFW 2015). White-tailed ptarmigan is listed as one of two “Climate Watch” bird species for the state (WDFW 2015, p. 5-16).

NatureServe’s Climate Change Vulnerability Index was used (CCVI) to predict vulnerability to climate change of 168 bird species that breed in the Sierra Nevada range of California (Siegel et al. 2014, entire). White-tailed ptarmigan was the only species to receive the most vulnerable rank, Extremely Vulnerable, while no species received the second-highest vulnerability ranking. The authors suggested that birds associated with subalpine or alpine habitats, and birds associated with aquatic habitats are more vulnerable to climate change than other groups.

Fewer ptarmigan individuals were found in late summer of 2009-2010 than 13 years prior at Logan Pass, Montana, much fewer than encountered in a study done in the same location during 1958–1962 (Benson and Cummins 2011, p. 241). White-tailed ptarmigan occurred at lower densities and occupied steeper slopes than in the past (Benson and Cummins 2011, p. 241). Summer flocks were also farther from snow and water, presumed to be a result of greater distances between snow, water, and forage as snowbanks have receded (Benson and Cummins 2011, p. 242).

Rock ptarmigan habitat use was studied in Switzerland at three spatial scales (Revermann et al. 2012, entire). At a meso and macro scale, maximum temperatures in July were the most important predictor of rock ptarmigan abundance, and at the countrywide scale the rock ptarmigan is constrained to regions with mean July temps below 50-54°F (10-12°C) (Revermann et al. 2012, p. 900). All climate change predictions from models were in agreement in predicting a significant loss of suitable habitat and a shift to higher altitudes (Revermann et al. 2012, p. 899).

These studies indicate habitat loss from climate change is likely to occur for Mount Rainier white-tailed ptarmigan. They indicate this source of stress is likely to impact habitat area and climate factors associated with distribution and abundance. We examine the influence of climate change and other factors on specific stressors to Mount Rainier white-tailed ptarmigan in the following sections.

4.2.2 Factors Directly Affecting Demographic Rates

These are the stressors that can directly impact demographic rates by affecting survival and reproduction. These factors do not operate through loss or alteration of habitat. The factors were drafted at an expert elicitation meeting held September 10, 2019, with land managers and state biologists.

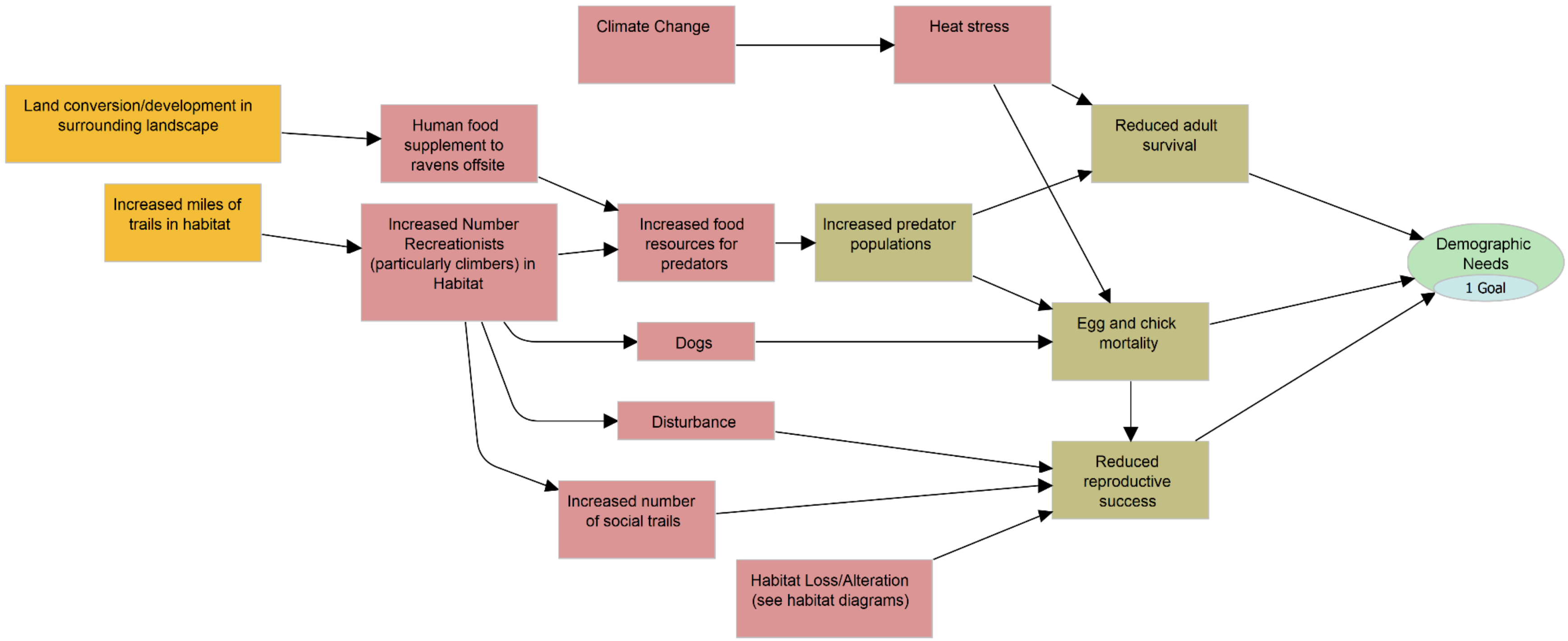


Figure 4. Factors potentially affecting demographic needs for Mount Rainier white-tailed ptarmigan. The factors were drafted at an expert elicitation meeting held September 10, 2019, with land managers and state biologists. Tan boxes furthest to the right represent potential stressors to Mount Rainier white-tailed ptarmigan. These are key population needs that are not being met currently or in the future. Additional tan boxes represent intermediate biological and physical factors that contribute to the stressors and are shown to clarify the nature of the relationships. Pink boxes are primary anthropogenic sources of stress, and yellow boxes are anthropogenic factors (e.g., management, social, or economic factors) that contribute to continued existence of the sources of stress.

4.2.2.1 Reduced Adult Survival

Adult survival is important to population growth, as high elasticity values for survival of 3+-year-old females indicate that perturbations affecting older birds would have the greatest impact on an alpine population of white-tailed ptarmigan (Sandercock et al. 2005b p. 22). Potential sources of mortality of adult Mount Rainier white-tailed ptarmigan include climate-related factors, predation, hunting, and non-hunting anthropogenic mortality.

Climate change may affect Mount Rainier white-tailed ptarmigan through direct physiological effects on the birds including increased exposure to heat in the summer, and increased exposure to cold in the winter. Mount Rainier white-tailed ptarmigan experience physiological stress when ambient temperatures exceed 21 degrees C (70 degrees F; Johnson 1968, p.1012), so their survival during warmer months depends on access to cool micro-refugia in their habitat; these cooler areas are found near snow, water, and under the shade of boulders. In the winter, white-tailed ptarmigan shelter from wind and cold in snow roosts. Snow roosting sites for Mount Rainier white-tailed ptarmigan have deep, fluffy snow with high insulation value. This generally means snow that is cold, relatively dry, and with abundant air spaces. Frequent melting and refreezing creates a hard surface crust (Peterson et al. 2014), that may make burrowing difficult. Additionally, warm winter temperatures, create wet, heavy snow (Peterson et al. 2014), which may decrease the insulation value of snow roosts. Absence of these roosts may reduce survival of ptarmigan by exposing them to cold temperatures.

Plumage mismatch could contribute to elevated predation. White-tailed ptarmigan have evolved to be cryptic through all seasons by molting frequently to match the substrate as snow cover changes. A change in timing of molt, or timing of snow cover, could limit the effectiveness of this strategy. However, molts are triggered by photoperiods, and not likely to change; therefore, timing of snow cover is critical to survival. In spring, a mottled pattern of white and brown can easily blend in while foraging at the borders of snow patches. In rock ptarmigan, the white plumage of males in spring represents one of the most conspicuous plumages known in birds, and males can be detected from approximately 0.6-1.2 mi (1-2 km) away (Montgomerie 2001, p. 430). When birds have molted white in the fall, and snow has not yet accumulated, they are highly conspicuous to predators and mortality can increase; start date of snow cover was negatively correlated with population growth rates in rock ptarmigan (Imperio et al. 2013, p. 6). In the North Cascades, all-white Mount Rainier white-tailed ptarmigan have been observed huddled and vulnerable as golden eagles flew overhead in late fall (Riedell 2019, pers. comm.). Fall accumulation of snow is more temporally variable than spring melt in the Cascades (Riedell 2019, pers. comm.). Later snow accumulation start dates resulting from climate change could therefore contribute to an increase in fall mortality. We do not have any data on Mount Rainier white-tailed ptarmigan survival rates and therefore cannot determine the severity or scope of this potential factor's effect on adult survival.

In the British Columbia portion of the range, white-tailed ptarmigan are hunted. Hunting regulations limit harvest rates with the goal of achieving neutral or positive population growth rates, but without population monitoring, we do not know the adequacy of these regulations. They are not hunted in Washington State (Revised Code of Washington, section 77.15.400), but ptarmigan in the Pasayten Wilderness are likely to cross the border into British Columbia, so populations in Washington may experience some hunting mortality. The scope and severity of this factor's effect on adult survival is unknown.

4.2.2.2 Reduced Reproductive Success

Anthropogenic sources of reduced reproductive success in other subspecies of white-tailed ptarmigan include predation and recreation. In particular, ravens are likely to take white-tailed ptarmigan nests and young (Schroeder 2019, pers. comm). Raven abundance has been positively correlated with predation of eggs or nestlings of other grouse, including eggs and nestlings of greater sage grouse (*Centrocercus urophasianus*, Coates et al. 2008, Coates and Delehanty 2010). The size and impact of raven populations in ptarmigan habitat can be influenced by the land use patterns in surrounding landscapes, and the amount of food waste in the habitat left by recreationists. The number of ravens below Camp Muir is quite high, and if these ravens are supported (directly and indirectly) by the climbing community, this could have an impact on ptarmigan productivity on the mountain (Schroeder 2019, pers. comm.). Ravens have been reported on Mount Rainier that were banded on landfills approximately 69 mi (110 km) away near Yakima, Washington (Stinson and Schroeder, pers. comm., 2019). Therefore, increases in cities, towns, highways, landfills, structures, orchards, and other sources of food within the larger landscape surrounding the Cascade Range are likely to result in an increase in ravens and other generalist predators. We do not know the current level of raven predation. We also do not know if other predators, such as weasels or skunks, occur at elevated levels within the areas occupied by Mount Rainier white-tailed ptarmigan.

Recreation can have both direct and indirect effects on the reproductive success of Mount Rainier white-tailed ptarmigan. Direct effects to reproductive success include both disturbance of individual ptarmigan, as well as the destruction of individual nests. Indirect effects include increased predation on individual ptarmigan due to elevated predation levels from recreation-related food litter mentioned above. Alpine Lakes, Goat Rocks, and Mount Adams are all very popular hiking locations in the National Forest system. Alpine Lakes has an average of 150,000 visitors annually (USFS 2020c, entire). Mount Rainier National Park had approximately 2.25 million visitors in 2019 (NPS 2020a, entire). North Cascades National Park drew nearly 1 million visitors in 2016 (NPS 2020b, entire).

In the spring, summer and fall, hikers, climbers, and mountain bikers may induce stress and disturbance/dispersal of ptarmigan, as well as destroy nests. In Colorado, dogs are also a significant recreation-related disturbance factor for white-tailed ptarmigan (Street 2019, entire). Dogs are allowed in Forest Service lands, but dogs (except service dogs) are prohibited in the National Park units. In the spring, summer, and fall, most locations with breeding and post-breeding habitat for Mount Rainier white-tailed ptarmigan have some level of use by day hikers and backpackers, as well as mountain bikers in some areas. Mount Rainier is a very popular location for mountain climbing in the summer months and the number of climbers is only likely to increase in the foreseeable future, especially given its proximity to the major metropolitan area of Seattle. Climbers attempt to summit in good weather anytime between May and September, however the peak climbing months are late July and August, which coincides with the Mount Rainier white-tailed ptarmigan breeding season (NPS 2020a, entire). Mount Adams also has mountain climbers and, although we could not verify annual use, the number of climbers is likely lower than Mount Rainier due to Mount Adams' lower elevation and more remote location.

In the winter, snowmobiles, snowcats, skiers, and snowshoers may induce stress and disturbance/dispersal in ptarmigan or negatively impact the availability of forage plants and snow roosting sites (Braun et al. 1976, entire; Hoffman 2006, entire). The loss of forage and snow roosting sites may influence body condition and subsequent reproductive success the next spring. The prevalence of snowmobiles and other winter recreation may have led to the extirpation of white-tailed ptarmigan in the Snowy Range of Wyoming (Braun and Wann 2017, p. 209). Developed ski areas within the range of Mount Rainier white-tailed ptarmigan include Mount Baker with a base elevation 3,500 feet and top elevation of 5,089 ft (North Cascades West population unit); Stevens Pass with a base elevation of 4,061 ft and a top elevation of top 5,865 ft (in the Alpine Lakes population unit), Crystal Mountain with a base elevation of 3,912 ft and a top elevation of 7,012 ft (in the Mount Rainier population unit), and White Pass with a base elevation of 4,500 ft and a top elevation of 6,500 ft (in the Goat Rocks population unit). Between 2002 and 2013 in Washington, there was a 105 percent increase in cross country skiing, 807 percent increase in snowshoeing and a 26 percent increase in "over-snow-vehicle" use, with 31.3 percent of Washingtonians participating in general winter recreational activities (WSP 2017). Snowmobiling is limited in the National Park areas: restricted from all but a small corner of Mount Rainier National Park, and from 94 percent of the North Cascades National Park designated as the Stephen Mather Wilderness; roads and motorized vehicles are prohibited in designated wilderness. About half of U.S. Forest Service land in the range of the Mount Rainier white-tailed ptarmigan is also in designated wilderness under 16 U.S.C. 551, 18 U.S.C. 3559 and 3571. Therefore, the extent of snowmobiling in winter habitat is likely to vary among population units as a result of wilderness designation. Ptarmigan population units vary from a low of 34 percent wilderness in the North Cascades East population unit to a high of 98 percent wilderness in Alpine Lakes population unit, and 54 percent overall (Table 3). Because Mount Rainier white-tailed ptarmigan winter use areas are unknown, we do not know how much of their winter habitat is affected by snowmobiling, ski areas, or other winter recreation.

Recreation levels have increased over time and are expected to continue to increase with human population and income growth, potentially increasing both direct (nest destruction and disturbance) and indirect effects (increased predation levels) to the species in the future. Outdoor recreation on Federal lands in general is projected to continue to increase (White et al. 2016; Bowler and Askew 2012). The activities projected to have the highest percentage growth in total days of participation include developed skiing and day hiking, and the least growth expected in motorized snow activities (White et al. 2016). Even a mid-level income growth/low population growth model (Bowker and Askew 2012, pp 111-120) forecasted from 2020 to 2050 national increases in the following: almost 30 percent in developed area skiing; over 23 percent in cross country skiing and snowshoeing; approximately 9 percent in snowmobiling; an approximately 22 percent in challenge activates including mountain climbing and rock climbing; 23 percent in day hiking; and, 15 percent in wilderness backpacking (Bowker and Askew 2012, pp. 111-120). Higher rates of either population growth or income growth rate would lead to higher predicted increases in all of these types of recreation (Bowker and Askew 2012, pp. 111-12). In summary, higher rates of summer and winter recreation in the future may affect the reproductive rates of populations of Mount Rainier white-tailed ptarmigan.

4.2.3 Factors Affecting Winter Habitat

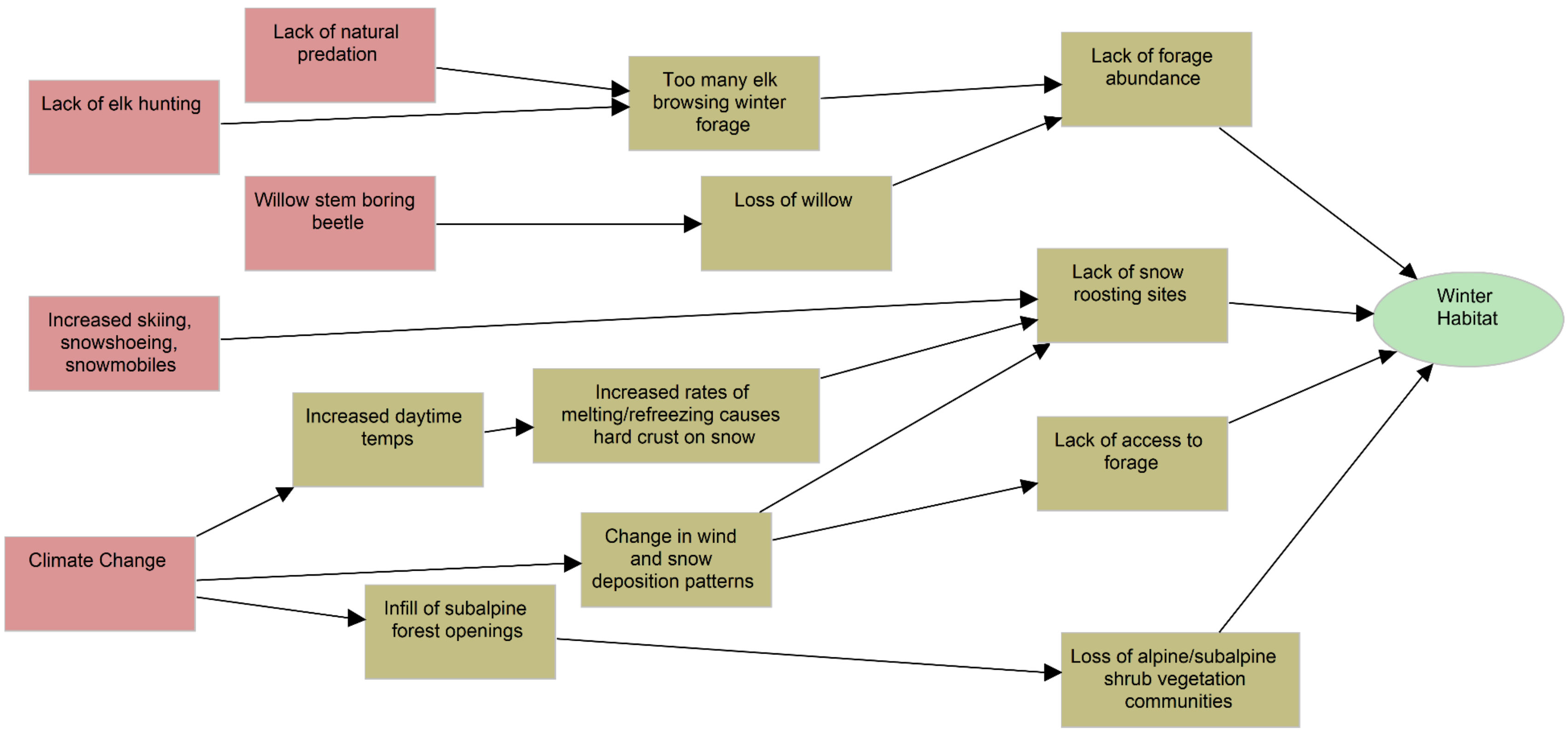


Figure 5. Factors potentially affecting winter habitat for Mount Rainier white-tailed ptarmigan. The factors were drafted at an expert elicitation meeting held September 10, 2019, with land managers and state biologists. Tan boxes furthest to the right represent potential stressors to Mount Rainier white-tailed ptarmigan. These are key population needs that are not being met currently or in the future. Additional tan boxes represent intermediate biological and physical factors that contribute to the stressors and are shown to clarify the nature of the relationships. Pink boxes are primary anthropogenic sources of stress.

4.2.3.1 Loss of alpine/subalpine vegetation communities from development

Road building, skiing-related development, and other development can destroy winter habitat for Mount Rainier white-tailed ptarmigan. Across the range of the species in both the United States and Canada, about half is in under wilderness designation where road development and motorized vehicles are generally prohibited (16 U.S.C. 551, 18 U.S.C. 3559 and 3571). Units with extant populations vary from a low of 34 percent wilderness in the North Cascades East population unit, to a high of 98 percent wilderness in the Alpine Lakes population unit (Table 2). Although the location of Mount Rainier white-tailed ptarmigan winter habitat is unknown, we expect it extends to lower elevations than summer habitat. At the lowest elevations it is likely to extend outside of wilderness and into areas where road building, ski area expansion, and other developments may occur.

Because we do not know the specific areas where Mount Rainier white-tailed ptarmigan winter, we cannot accurately estimate the spatial extent of current or future recreational infrastructure development in winter habitat. Bowker and Askew (2012, pp. 111-120) forecasted national increases in the following types of recreation from 2020-2050: almost 30 percent in developed area skiing; over 23 percent in cross-country skiing and snowshoeing; and, approximately 9 percent in snowmobiling. Based on these forecasts, we expect increases in winter recreational infrastructure. If winter habitat is lost to development, the severity of this stressor would be very high, and the effects are irreversible.

4.2.3.2 Loss of alpine/subalpine vegetation communities from climate change

Wang et al. (2002, p. 83) found a negative relationship between white-tailed ptarmigan population growth rate and winter minimum temperature in Rocky Mountain National Park. Their models projected substantial decline of the ptarmigan population at the Park using the CCC and Hadley model-based scenarios of future warming. The exact mechanisms for how winter temperature affected overwinter condition and growth rates were not investigated.

One of the primary mechanisms for climate change impacts on wintering white-tailed ptarmigan is likely to be conversion of forest openings (e.g., meadows) to subalpine forests, which are not suitable habitat for white-tailed ptarmigan. Infill of subalpine openings with trees has already been recorded at Mount Rainier National Park, and other areas (Franklin et al. 1971; Stueve et al. 2009, entire). Subalpine meadows have been increasingly displaced by subalpine tree species throughout northwestern North America (Fagre et al. 2003, p. 267).

4.2.3.3 Lack of winter forage abundance

Winter forage is important to white-tailed ptarmigan, as they gain weight over the winter (May 1975). Overwinter survival and spring condition that influence nest success depend on availability of adequate amounts of winter forage. We have no information on winter forage used by Mount Rainier white-tailed ptarmigan, but based on winter diet recorded for other subspecies of white-tailed ptarmigan, we suspect they use alder, birch, and willow shrubs (see the diet section for more information).

Wind exposes shrubs for forage, and wind deposition patterns may change with climate change as a result of decreasing wind expected throughout the Cascades (Luce et al. 2013, p. 1363). As a result, winter forage may either be buried, or too high above snow level for ptarmigan to easily reach.

Elk are suspected to limit winter forage in Colorado, where declines in one white-tailed ptarmigan population have been attributed to excessive browsing by elk (Braun et al. 1991, entire). This is corroborated by research conducted by Wann (2019, pers. comm.) in Rocky Mountain National Park. In contrast, elk population size was not related to white-tailed ptarmigan population growth rates at Rocky Mountain National Park (Wang et al. 2002, p. 83) but this correlation does not account for time lags in ptarmigan population growth rates (Wann 2019, pers. comm.). This source of forage loss may vary regionally in severity. Elk are a plausible source of forage loss for Mount Rainier white-tailed ptarmigan, although they may have more alternative winter forage options than white-tailed ptarmigan in Colorado (Wann 2019, pers. comm.). We cannot precisely map the overlap in the species' distributions until we determine where Mount Rainier white-tailed ptarmigan winter.

Another potential source of loss of winter forage is the exotic, invasive willow stem boring beetle (*Cryptorhynchus lapathi*; Chestnut 2019, pers. comm.). This European species impacts willow stands where it occurs (Furniss 1972, p. 1; Hannon and Brown 2017, pp. 2-3). We know it is likely to impact willow stands, but do not know the scope or severity of its impact throughout the range of Mount Rainier white-tailed ptarmigan. It is documented in Washington and Oregon, but we found no distribution data. Broberg et al. (2002, p. 564 - 565) did not find the species in subalpine forests of British Columbia, but did find the species' range had doubled since 1965, and was highly correlated with temperature; the recent rapid spread appears to be related to climate warming (Pogar 2010, in Burr 2020, pers. comm.). Surveys in 2018-2019 indicate that it does seem to be spreading into new areas, including higher elevations, of ecosystems of British Columbia (Engelmann spruce - Subalpine fir (White 2020, pers. comm.).

4.2.3.4 Lack of access to winter forage

Limited access to forage may also be a concern. Wind sweeps snow off ridges, which exposes shrubs, or the tips of shrubs, for foraging ptarmigan. Wind also has a strong influence on the pattern of snow loading across the landscape, causing a patchy pattern where there is less snow in wind-blown areas and more in areas protected from wind. This snow loading pattern, in turn, can affect the number and severity of avalanches, which can both create opportunities to access or to bury white-tailed ptarmigan forage. A reduction in wind may reduce access to forage. Wind is projected to decrease in the Pacific Northwest as the climate changes (Luce et al. 2013, entire), so we expect this source of stress will likely occur in the future.

4.2.3.5 Lack of snow roosting sites

As described previously in the winter ecology and winter habitat sections of this SSA, snow roosting protects white-tailed ptarmigan from both wind and cold ambient temperatures. Snow roosting sites should have deep, fluffy snow with high insulation value. This generally means snow that is cold, relatively dry, and with abundant air spaces. In the Pacific Northwest, changes in snowpack in the colder interior mountains (e.g., eastern Cascades) will largely be driven by changes in precipitation, while changes in snowpack in the warmer maritime mountains (e.g., western Cascades) will be driven largely by changes in temperature (Hamlet 2006, pp. 40-42). Factors that may affect snow quality include frequent melting and refreezing, which creates a hard surface crust. Additionally, rain on snow events, which are predicted to increase under most climate change scenarios, can lead to surface melt and a firm crust and denser snow. Another factor that may affect snow quality is warm winter temperatures, which would create wet, heavy snow. Currently, snow in the western Cascades is generally wet and heavy, but we do not know if these snow characteristics affect the quality or availability of snow roosts for Mount Rainier white-tailed ptarmigan, thus exposing the birds to wind and cold ambient temperatures. At some point in the future, winter temperatures might become so warm that white-tailed ptarmigan would not need snow roosts to maintain body temperature, but we do not know the temperature range at which snow roosts are essential. As discussed earlier, winter winds are expected to decline, which may or may not reduce the need to access snow roosts, depending on microclimate wind patterns. Observations of fresh snow roosts in spring conditions in the Sierra Nevada indicate they are used even in relatively warm conditions (T. Frederick, pers. observ.). As discussed in previous sections, snowmobile trails, ski trails, and other recreational uses could also decrease the availability of snow roosting sites through snow compaction (Braun et al. 1976, p. 8).

4.2.4 Factors affecting Breeding Season Habitat

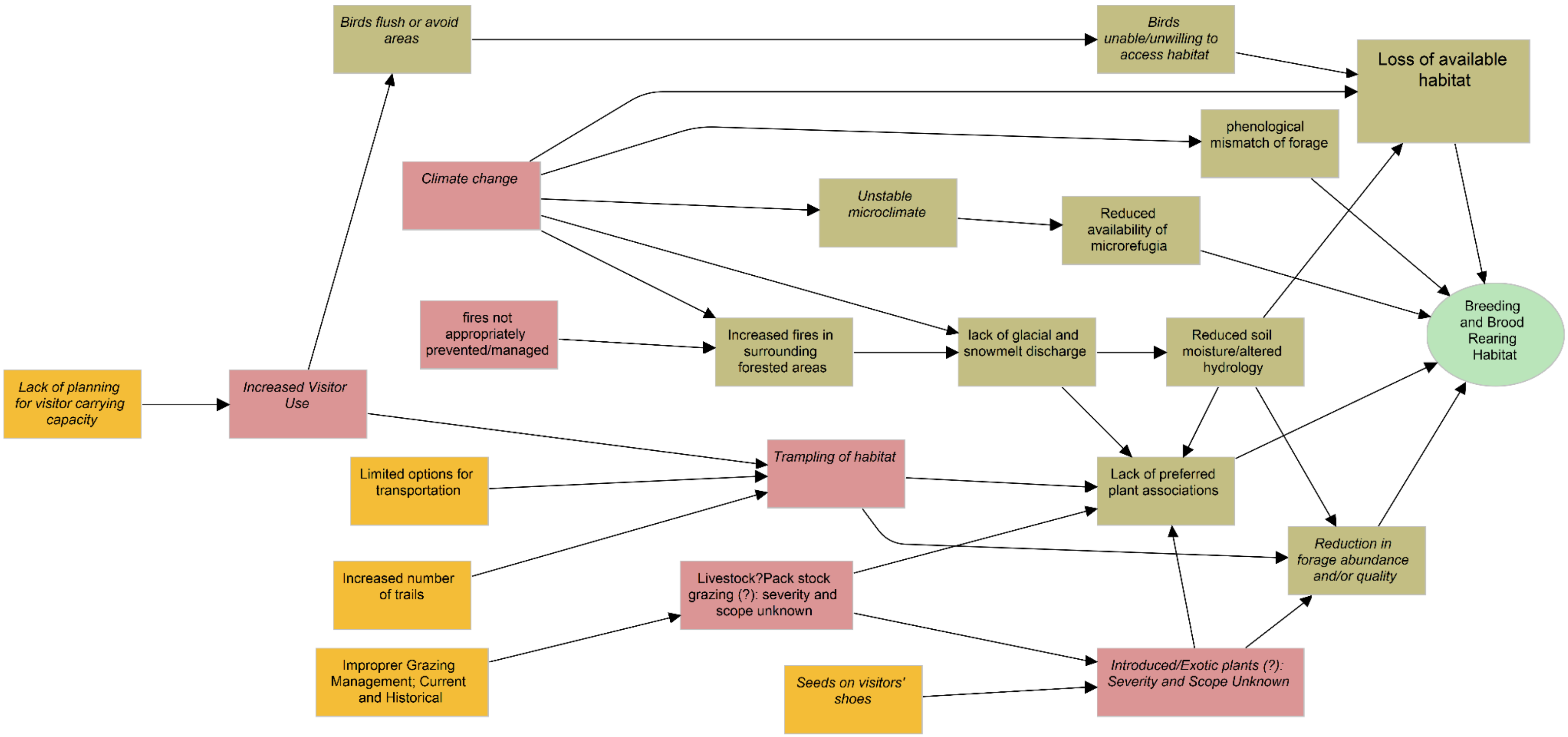


Figure 6. Factors potentially affecting breeding and brood-rearing habitat for Mount Rainier white-tailed ptarmigan. The factors were drafted at an expert elicitation meeting held September 10, 2019, with land managers and state biologists. Tan boxes furthest to the right represent potential stressors to Mount Rainier white-tailed ptarmigan. These are key population needs that are not being met currently or in the future. Additional tan boxes represent intermediate biological and physical factors that contribute to the stressors and are shown to clarify the nature of the relationships. Pink boxes are primary anthropogenic sources of stress, and yellow boxes are anthropogenic factors (e.g., management, social, or economic factors) that contribute to continued existence of the sources of stress.

4.2.4.1 Phenological mismatch

Long-term demographic data for two sites in Colorado indicate seasonal weather does not strongly affect reproduction, as measured by number of chicks per hen (Wann et al. 2014). This conclusion implies that climate change impacts on seasonal weather will have no influence on reproductive success of white-tailed ptarmigan populations. However, the number of chicks per hen is only one measure of reproductive success, and this study did not consider potential mechanisms for how weather may affect other measures of reproductive rate (Wann et al. 2019). To investigate a mechanism for how climate may affect white-tailed ptarmigan reproduction, the same authors related the effects of the phenology of plant growth on reproductive success, as measured by white-tailed ptarmigan chick survival (Wann et al. 2019, entire). When they related the phenology of the peak of alpine plant growth (measured by NDVI) to chick survival, they found the timing of peak plant growth influences chick survival, and the peak in NDVI should be in the first two weeks after hatch to benefit white-tailed ptarmigan reproductive success. Although chicks less than three weeks old forage on insects, this study found the peak in NDVI is related to insect abundance as well as to plants upon which older chicks forage (Wann et al. 2019). If the peak in NDVI occurs outside of this crucial post-hatch period, the resulting phenological mismatch negatively affects chick survival, which would decrease reproductive success at a population scale. The seasonal phenology of winter snowfall and spring melt have strong effects on the annual fecundity of ptarmigan (Clarke and Johnson 1992; Martin 2001; Martin and Wiebe 2004).

4.2.4.2 Habitat alterations/loss of forage due to altered hydrologic patterns

As we discussed in the habitat section, white-tailed ptarmigan are associated with moist alpine vegetation that supports nutritious forbs and abundant insects for chicks. Moist vegetation requires moist soils, which are maintained by snowpack, rain, and meltwater from glaciers or permanent snowfields. The timing of melt and spatial arrangement of snow can have a strong influence on growth, phenology, and plant species composition of alpine meadows (Peterson et al. 2014, p. 104). The timing of snowmelt was the strongest environmental factor explaining species composition and distribution of plant communities in the North Cascades (Douglas and Bliss 1977, p. 118).

The quality of snow can also influence plant phenology and community composition. Increased snow density expected from climate change and other anthropogenic sources reduces soil insulation and leads to lower minimum soil temperatures, which delays flowering phenology (Rixen et al. 2008, p. 571). Compacted snow is also associated with later melt-out dates and increased nitrogen mineralization (Rixen et al. 2008, p. 571). These influences are expected to negatively impact plant species composition. These results were also more pronounced for compacted artificial snow, and are expected to be greater on ski runs where snow mass is greater than on experimental sites (Rixen et al. 2008, p. 573).

In the Cascades, precipitation falls primarily during the cooler months (October through March), while potential evapotranspiration is highest in the warmer and drier months (April through September), creating summer water deficits where evaporative demand exceeds water storage capacity (Peterson et al. 2014, p 26). At higher elevations, winter snowpack can store a significant portion of winter precipitation and release it to the soil during spring and early summer thereby reducing the duration and magnitude of summer soil water deficits (Peterson et al. 2014, p 26). Reduced snowpack, earlier snowmelt, and higher evapotranspiration rates resulting from climate change are likely to enhance summer soil drying and reduce soil water availability, thus increasing these soil water deficits (Elsner et al. 2010, p. 245).

A substantial decrease in perennial snow cover is projected for the North Cascades, and many areas of snow cover are replaced by bare ground in future scenario images (Patil et al. 2017, p. 5600-5601). Decreased winter wind may be one factor causing reduced precipitation and snowpack in the western Cascades (Luce et al. 2013, entire; Luce 2019, entire). Throughout the Pacific Northwest, patterns in snowpack change will vary with location. Changes in snowpack in the colder interior mountains will largely be driven by changes in precipitation, while changes in snowpack in the warmer maritime mountains will be driven largely by changes in temperature (Hamlet et al. 2005, pp. 4554-4556). Some high-elevation sites that maintain freezing winter temperatures may accumulate additional snowpack as additional winter precipitation falls as snow (Peterson et al. 2014, p. 25). The amount of moisture the snowpack can hold, and subsequently release upon melting, is called snow water equivalent. Increasing melt events are believed responsible for declining snow water equivalent in western states (Mote et al. 2005, p. 45). Snow water equivalent declines 16 percent for every 1.8°F (1°C) rise in temperature, and is estimated to have declined by 8-16 percent from 1984 to 2014 and projected to decline an additional 11-20 percent by 2050 (Casola et al. 2009, p. 2769).

Glacier meltwater also provides a significant portion of moisture to watersheds. At the basin scale, glacier melt supplies 2-14 percent of summer discharge in the Cascades and up to 28 percent of discharge by September (Frans et al. 2018, p. 11); the proportion is likely much greater in the high elevation subbasins, which have a smaller catchment area to supply discharge from snow or rain. Glacial melt contribution to summer discharge is likely to decline in the future, however. Geologic mapping data, old maps and aerial photos, and a recent inventory indicate that glacier area has declined 56 percent at North Cascades National Park between 1900 and 2009 (Dick 2013, p.59). On Mount Adams, total glacier area decreased by 49 percent (12.17 mi^2 to 6.25 mi^2 (31.51 km^2 to 16.18 km^2)) from 1904 to 2006 at about 0.37 ac (about 0.15 km^2) per year (Sitts 2010, p. 384).

Although there are some exceptions, most Washington glaciers are receding (Snover et al. 2013, p. 2-3). Future glacier area is projected to decline in both RCP 4.5 and RCP 8.5 scenarios throughout the Washington and Northern Oregon Cascades (Frans et al. 2017, p. 13). Throughout the northern Washington Cascades, glacial area has decreased 56 percent between 1900 and 2009 (Roop et al. 2020, p. 5). Regional modelling of the North Cascades indicates glaciers will retreat 92 percent in the period from 1970 to 2100 under RCP 4.5 and 96 percent under RCP 8.5 (Gray 2019, p. 34). As temperatures increase, glaciers initially melt quickly and contribute an increased volume of water to the system, but as glacial mass is lost, their contribution of water to the system decreases over time. Glacier melt in many of the watersheds of the eastern Cascade Range and low-moderate elevation watersheds of the western Cascades have already peaked, or will peak in the current decade (Frans et al. 2018, p. 20). Because the timing of glacial discharge peaks will vary from glacier to glacier, we expect decreases in available moisture to some alpine meadows, but increases in others, early in the twenty-first century. Later in the century, we expect all areas to suffer significant losses of glacier melt (Frans et. al 2018, p. 20). Total discharge in August and September from snowmelt, rain, and glacial melt in a sample of Cascade watersheds is already below the 1960-2010 mean, and is expected to continue to drop through 2080 (Frans et. al 2018, p. 15). Glaciers on the east side of the Cascade crest, where the precipitation regime is drier, show the strongest response to climate in both historical and future time periods, and will be the most sensitive to a changing climate (Frans et al. 2018, p. 17).

Based on these projections for temperature, snowpack, timing of melt, and glacial mass discharge, we expect strong alterations of the hydrology of alpine systems to occur as climate change continues. Many of these changes will become more severe in the latter half of the century as glacial recession ceases to provide a meltwater buffer that is maintaining these systems now. Where these hydrologic changes do not cause complete loss of summer habitat (see the habitat loss section, below), we expect habitat quality to decline as plant moisture, abundance, species composition, and invertebrate abundance decrease.

4.2.4.3 Loss of cool microclimate refugia

As discussed in the habitat loss section (below), cool microclimates offered by snow, water, and boulders are important for providing refugia from hot summer temperatures and assisting thermoregulation. We expect these microclimate refugia to become less abundant as glaciers and snowbanks recede (see the altered hydrology section, above, for documentation on those projections). Additionally, as temperatures increase, fewer sites will be effective at maintaining microclimates suitable for white-tailed ptarmigan.

4.3.4.4 Habitat loss (loss of preferred plant associations) from climate change

As described in the section above, the current distribution of vegetation in the North Cascades is a function of climate, topography, soils, and disturbances (Littell et al. 2014, p. 115). The lower limit of alpine vegetation is defined by treeline, which is determined by cold winter temperatures, short growing seasons, and harsh physical conditions such as avalanches and wind (Littell et al. 2014, p. 115). Glaciers, permanent snow, or barren parent material defines the upper limit of alpine vegetation.

The IPCC (2019, pp. 2-9) projects with very high confidence that surface air temperatures in high mountain areas will rise by 0.54 degrees F (0.3 degrees C) per decade, generally outpacing global warming rates regardless of RCP scenario. As the climate becomes warmer, vegetation communities are expected shift their distributions to higher elevations. The lower elevation limit of alpine vegetation communities used by white-tailed ptarmigan during the breeding and post-breeding seasons is defined by treeline, which is expected to rise globally (IPCC 2019, p. SPM-25) and within Washington (Stueve et al. 2009, entire), thus eliminating existing subalpine meadows (important wintering habitat). The narrow band of alpine vegetation will be lost unless the alpine vegetation communities are able to expand their upper elevation limit at a rate that matches or exceeds the rate of loss at their lower elevation limit at treeline. Such expansion is unlikely since creation of soils capable of supporting white-tailed ptarmigan forage vegetation from barren parent material will take multiple decades.

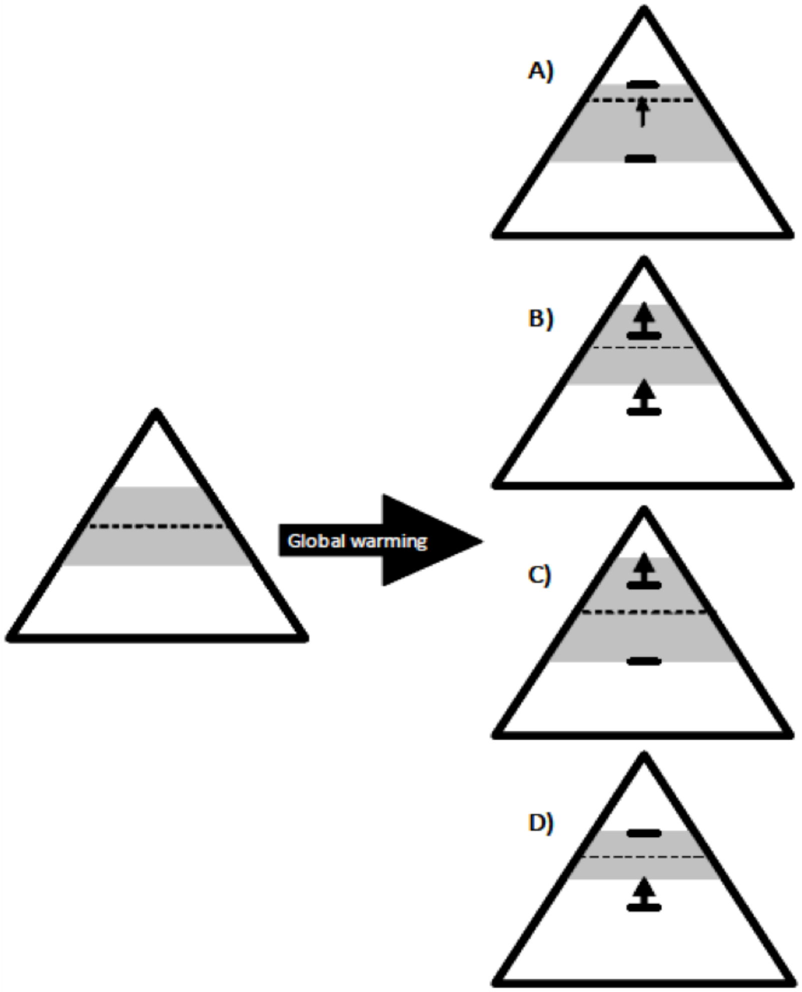


Figure 7. Four potential scenarios (A-D) for elevation shifts of species and vegetation communities in response to climate change. The breeding and post-breeding season habitat occupied by white-tailed ptarmigan is the band of alpine vegetation above treeline and below areas with no alpine vegetation (currently occupied by rock or permanent snow), as indicated by the gray band on the figure. The lower black bar represents treeline and the upper black bar indicates the upper limit of alpine vegetation as determined by rock, permanent snow, or unvegetated glacial till. On mountains at lower latitudes or lower in elevation, the upper limit may be the top of the mountain. A) Shift in abundance in the current range, B)Shift of the whole range upslope, C)Expansion upslope at the high end of the range, or D)Contraction, with a shift upslope at the low end of the range and no upward shift at the high end of the range. Figure adapted from climateecology.wordpress.com.

Factors contributing to the increase in elevation of treeline include increased temperatures, longer growing seasons, increased carbon dioxide, and decreased wind. Growing seasons are expected to lengthen because temperatures will become warmer at earlier dates, and also because snow will melt off vegetation earlier. These conditions will enable trees to grow where they may have been limited by soil temperature, frost, or growing season length before. Decreased wind will allow some krummholz to grow taller into tree form, as wind in alpine areas can be the main factor limiting vegetation height and the growth of trees (Zwinger and Willard 1972, pp. 55-61). Wind is projected to decrease with climate change in the Pacific Northwest (Luce et al. 2013, p. 1361). Conversely, increased fire in subalpine forests could conceivably constrain treeline advances. However, considering numerous factors affecting susceptibility to burning, local factors, and tree regeneration, the transition zone will likely widen, and a climate-driven rise in treeline will not likely be counteracted by fire (Cansler et al. 2018, p. 17).

Strong treeline advances have already been found in some areas, such as Mount Rainier National Park (Stueve et al. 2009, entire). Globally, treelines have either risen or remained stable, with responses to recent warming varying among regions (Harsch et al. 2009, entire). The influence of climate on increasing treeline elevation is affected by physical barriers (e.g., cliffs), soils, topography, and disturbances (Holtmeier and Broll 2005, entire). In addition to moving upslope, forests are expected to infill subalpine meadows (important wintering habitat for white-tailed ptarmigan). Woody vegetation cover has increased near the Alpine Tundra – Mountain Hemlock ecotone on Vancouver Island from 1962 to 2005, consistent with infill predictions (Jackson et al. 2015, p. 440).

Although treeline is expected to move upslope into what is currently alpine vegetation, a corresponding upslope movement of alpine vegetation into new higher elevation areas is less certain. In some areas, alpine vegetation will not be able to expand upslope if constrained by cliffs, parent rock material, remaining glaciers, ice, permanent snow, or the upper elevation limit of the mountain range. In other areas, an upward expansion of alpine vegetation will be limited by soil development and moisture availability, as glacial till and other newly exposed alpine substrates have few nutrients or the water-holding capacity necessary to support plants. Where upslope migration of plant communities is able to occur, habitat for white-tailed ptarmigan will not be available until primary succession proceeds to the stage where white-tailed ptarmigan forage plants and insects are present in sufficient abundance and composition to support all ages of foraging ptarmigan.

The predominant upper elevation limit of alpine vegetation communities used by white-tailed ptarmigan during the breeding and post-breeding seasons is defined by barren rock or snow line (the lower elevation limit where snow persists throughout the year). The elevation of snow line varies with latitude, topography, aspect, and the amount and timing of snowfall in any given year. Due to variable precipitation and winter temperatures, such as those caused by the El Niño-Southern Oscillation and Pacific Decadal Oscillation, the amount of snowfall in the Pacific Northwest is highly variable (Fagre et al. 2003, entire). As a result, the amount and timing of snow accumulation varies significantly among years, causing large variations in the amount and location of semi-permanent snowbanks during the breeding season. Snow line is at lower elevations on top of glaciers than on non-glaciated areas because the glaciers keep the snow cold on the ground surface, and slow melting (Riedell 2019 pers. comm.). These factors can influence the elevation of snowline by hundreds of meters. Snowbed vegetation is adapted to this wide range of variation in snowline elevation and timing of snowmelt, and plants exhibit adaptations such as subnivean (under snow) growth (Björk and Molau 2007, p. 36). Once snow does recede, they grow and bloom rapidly. However, there is a limit to these adaptations, and once snowline recedes to elevations higher than historical levels, the newly-exposed areas that were once beneath the snow will not have snowbed vegetation, seeds, or even soil to support plant growth. These areas will need to undergo the processes of primary succession before alpine vegetation can grow. When snow recedes to elevations higher than the historical range of variation, it will not become ptarmigan habitat for decades. Only when dwarf willows, sedges, and other ptarmigan forage species colonize in sufficient area and abundance will the site become suitable for white-tailed ptarmigan.

The glacial forefront (the area formerly under a glacier, and newly exposed by the recession of the glacier) of Lyman Glacier in the North Cascades represents an example of the manner and rate in which this primary succession may occur. The succession at this forefront was classified in four phases (Jumpponen et al. 1998, p. 240). Note this study did not classify the barren phase in the first twenty years following glacial recession:

1. A 20- to 30-year-old phase characterized by scattered individuals or small patches of the early seral plant species *Juncus drummondii, J. mertensianus, Luzula piperi, Saxifraga ferruginea and S. tolmiei*

2. A 30- to 50-year-old phase characterized by the same early seral species as in phase 1, and in addition scattered willow shrubs, principally *Salix phylicifolia* and *S. commutata*, and occasional *Pinaceae*

3. A 50- to 70-year-old phase similar to phase 2 and showing denser vegetation

4. A 70- to 100-year-old phase, characterized by species of *Cyperaceae, Ericaceae, Juncaceae, Onagraceae, Saxifragaceae, Scrophulariaceae and Pinaceae (Abies lasiocarpa, Larix lyallii, Tsuga mertensiana)*.

We therefore expect successional process, if it occurs, to take at least 20 years to develop limited white-tailed ptarmigan forage plants (*Saxifrage* species), and 70-100 years to mature to full habitat with lush meadows and ericaceous subshrubs. Thus, even if conditions are right (e.g., suitable parent material, topography, etc.), and vegetation succession does occur, it would take so long that Mount Rainier white-tailed ptarmigan would not be able to use it for many generations (assuming a generation length of 4.1 years, (Bird et al. 2020, supplement Table 4), 5 to 24 generations). In the meantime, these glacial forefront areas would be a gap in breeding and post-breeding habitat.

We also expect some areas will lack appropriate conditions to succeed to alpine plant communities at all. Physical characteristics of a site may change over very short distances, and although these differences may seem minor, they may result in large differences in soil moisture, temperature, and length of growing season, all factors that can limit which vegetation communities can occur at a site (Douglas and Bliss 1977, entire; Littell et al. 2014, p. 115). Migration of alpine meadow communities to higher elevations may be limited by the soil fungal communities needed for mycorrhizal associations, which in turn need suitable abiotic microenvironments to establish (Jumpponen et al. 1999, entire). Each of these factors may influence the ability of a site to support alpine vegetation suitable for ptarmigan.

Considering all these factors, we expect alpine habitat for Mount Rainier white-tailed ptarmigan will exhibit the response to climate change shown in (D) of Figure 7. That is, the lower elevation will rise due to rising treelines, but the upper elevation rise will be constrained both spatially and temporally.

Where habitat remains, vegetation species composition is likely to include fewer species that rely on snowmelt from glaciers or permanent snow, or are less tolerant of hotter, drier conditions. Alpine stream types will progress from being fed by glacier flats, to steep glacier areas, to permanent snowfields to seasonal snow. Accordingly, the associated riparian vegetation will likely have less herbaceous cover, woody shrubs, and willow where glaciers are lacking and melt comes from permanent snowfields of seasonal snow (McKernan et al. 2018, p. 525).

4.2.4.5 Habitat loss and alteration from other sources

Some losses of alpine habitat could occur from trail expansion and installation of helicopter landings (J. Ransom, pers. comm.), however, we expect the area affected to be small and did not include this in our estimation of future habitat area. There could potentially be additional losses from increasing levels of recreation, and associated off-trail use (permitted or not) and trampling. Disturbance from human use may cause white-tailed ptarmigan to be unwilling to occupy habitat. Also associated with recreational use levels are impacts on alpine vegetation from pack stock and spread of invasive plants. As described in the demographic section, above, recreation levels have increased over time and are expected to continue to increase with human population and income growth. Outdoor recreation on Federal lands in general is projected to continue to increase (Bowker and Askew 2012; White et al. 2016). The activity projected to have the highest percentage growth in total days of participation is day-hiking (White et al. 2016). Even a mid-level income growth/low population growth model (Bowker and Askew 2012, pp 111-120) forecasted from 2020 to 2050 shows national increases of: approximately 22 percent in challenge activities (e.g., mountain climbing and rock climbing); 23 percent in day hiking; and, 15 percent in wilderness backpacking (Bowker and Askew 2012, pp. 111-120). Higher rates of either population growth or income growth rate would lead to higher predicted increases in all of these types of recreation (Bowker and Askew 2012, pp. 111-12).

4.2.5 Factors affecting Post-breeding Habitat

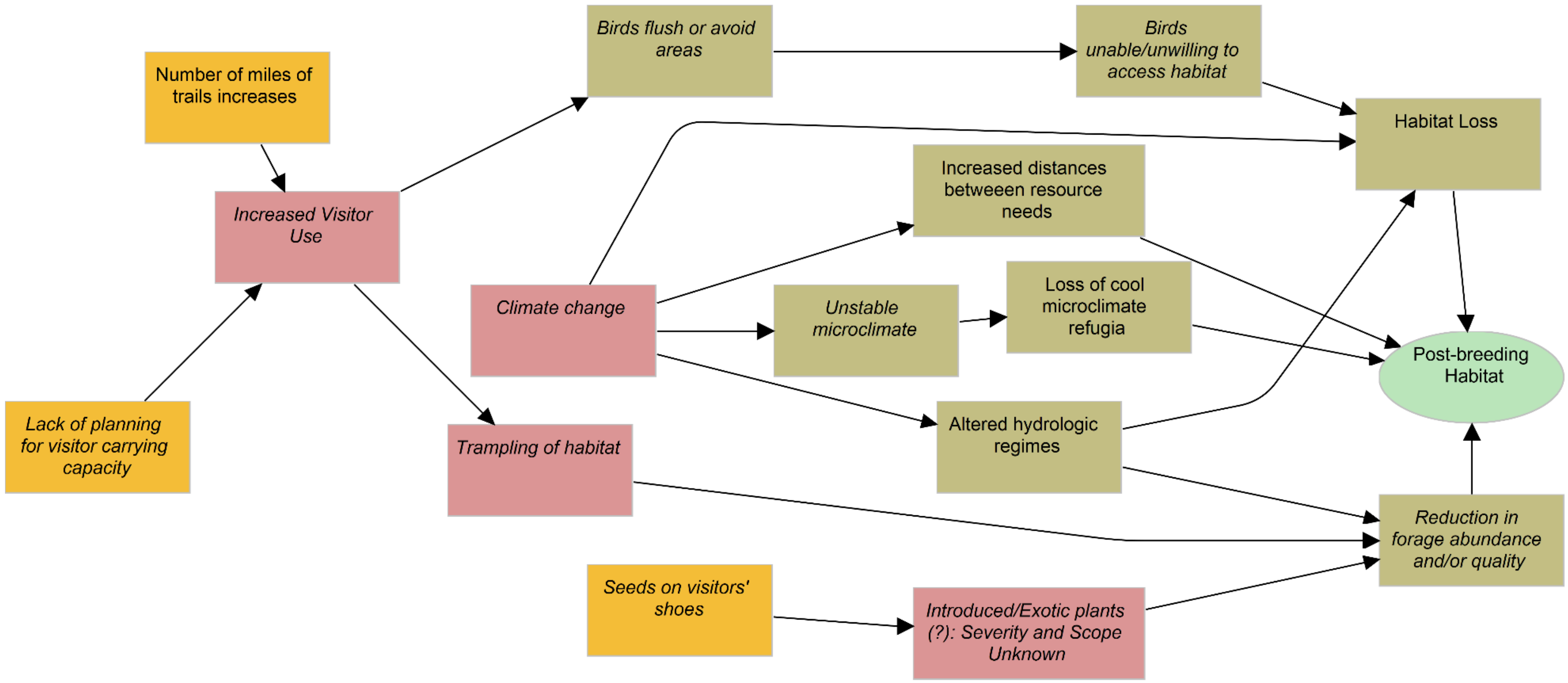


Figure 8. Factors potentially affecting post-breeding habitat for Mount Rainier white-tailed ptarmigan. The factors were drafted at an expert elicitation meeting held September 10, 2019, with land managers and state biologists. Tan boxes furthest to the right represent potential stressors to Mount Rainier white-tailed ptarmigan. These are key population needs that are not being met currently or in the future. Additional tan boxes represent intermediate biological and physical factors that contribute to the stressors and are shown to clarify the nature of the relationships. Pink boxes are primary anthropogenic sources of stress, and yellow boxes are anthropogenic factors (e.g., management, social, or economic factors) that contribute to continued existence of the sources of stress.

4.2.5.1 Habitat loss and alterations in forage abundance and quality

The sources of post-breeding habitat loss, and alterations in forage abundance and quality, are the same as those discussed, above, for loss of breeding habitat. However, the influence of altered hydrologic regimes on habitat and forage abundance and quality is likely to be greater during the post-breeding season. As discussed with breeding habitat, above, reductions in snowpack and glacial mass are expected to reduce the amount of moisture available to alpine streams and soils. During the post-breeding season much of the seasonal snow has already melted, and then meltwater from glaciers and permanent icefields has an even larger influence on alpine vegetation.

4.2.5.3 Loss of cool microclimate refugia

Compared to random sites, ptarmigan flock locations in Montana tended to have lower average high ambient temperatures, lower black globe temperatures, and lower average high black globe temperatures, although none of these comparisons were statistically significant (Benson and Cummins 2011, p. 241). White-tailed ptarmigan have been observed throughout their range seeking refuge from summer sun in the shade of boulders and near snow (see discussions in breeding and post-breeding habitat sections). Other climate microrefugia include cool air depressions, glaciers, and permanent snowfields. All of these areas, except boulders, will decrease as the climate warms. Glaciers in the Cascades are already retreating rapidly in both area and volume (Dick 2013, entire), and we expect their availability to provide cool microrefugia for white-tailed ptarmigan will decrease proportionally. Glaciers in the area of Mount Rainier white-tailed ptarmigan populations have receded by 12 percent (Thunder Creek; 1950-2010) to 31 percent (Nisqually River; 1915-2009) (Frans et al. 2018, p.10). We also expect permanent snowfields to decrease in area as the climate warms and these features melt.

4.2.5.4 Increased distances between resource needs

As glaciers and permanent snow recede, they will expose barren lands with no vegetation. As described earlier, the decades-long process of primary succession will need to occur on these areas before they can provide habitat. In the meantime, these barren lands will constitute a gap between forage and the cool microsites provided by snow. In 2009–2010, ptarmigan at Logan Pass in Glacier National Park, Montana, chose habitat significantly farther from snow and marginally farther from water, with higher soil moisture and a steeper slope than ptarmigan in 1996 and 1997 (Benson and Cummins 2011, p. 242). Although this may imply they needed snow less in the later study, these authors suggested, “With the rate of long-term snow loss, areas near perennial snow that are exposed by late summer have been under snow for at least the last several thousand years. Further, some of those areas have had soil removed by recent glaciation and remain completely devoid of vegetation. Change in the proximity of White-tailed Ptarmigan in late summer to water and snow might thus be due to a tradeoff between thermal needs and the need for food at flocking locations” (Benson and Cummins 2011, p. 244).

4.3 Conservation Measures Benefitting the Species

The Transboundary Connectivity Project included white-tailed ptarmigan as a focal species. Members created conceptual models of stressors to the species and designed strategies to abate threats.

Mount Rainier white-tailed ptarmigan habitat in Washington is almost exclusively on federal lands (94 percent of habitat area). Much of these federal lands have Wilderness designation, which provides protection from roads, developments, and other major sources of habitat destruction in most areas. The Pasayten Wilderness is protected from mining by an administrative withdrawal (Kuk 2019, pers. comm.).

The WDFW considers the white-tailed ptarmigan a game bird, but does not have a hunting season on the species. Take or possession of the species would be a season violation under the Revised Code of Washington, section 77.15.400 (Washington State Legislature 2020). White-tailed ptarmigan are a "Species of Greatest Conservation Need" in the State Wildlife Action Plan (Washington Department of Fish and Wildlife 2015, p. 3-18). The Species of Greatest Conservation Need list is intended to inform voluntary conservation of species and habitats for a wide variety of state agencies and conservation organizations (Washington Department of Fish and Wildlife 2015, p. 3-2). The list is the basis for the State Wildlife Action Plan, and serves as an early warning system for species in need of additional conservation attention (Washington Department of Fish and Wildlife 2015, p. 3-2). Actions recommended include: 1) Continue to minimize human disturbance (direct and indirect) in white-tailed ptarmigan habitats, 2) Conduct outreach; and, 3) Conduct surveys (Washington Department of Fish and Wildlife 2015, Appendix A2, p. 22). The species is not on the list of priority habitats and species (PHS). WDFW is making efforts to better understand the distribution and abundance of the species by soliciting observations from birding enthusiasts, hikers, backpackers, mountaineers, skiers, snowshoers, and other recreationists that visit ptarmigan habitat (Stinson 2019, pers. comm).

With the exception of the Vancouver Island subspecies, white-tailed ptarmigan in British Columbia are listed as a G5 species (least concern) by the British Columbia Conservation Data Center (B.C. Conservation Data Centre 1996, entire).

White-tailed ptarmigan are not on the sensitive species list for USFS forests within the range of Mount Rainier white-tailed ptarmigan, and they are therefore not protected from direct mortality effects from USFS activities.

White-tailed ptarmigan are not protected in either country by the Migratory Bird Treaty Act.

Benefits resulting from designated critical habitat of other alpine and subalpine species could protect Mount Rainier white-tailed ptarmigan habitat. The only designated critical habitat that overlaps the range of the Mount Rainier white-tailed ptarmigan is that for Canada lynx in the North Cascades. The physical and biological features (PBFs) and primary constituent elements for lynx critical habitat include, among others:

(1) Boreal Forest Landscapes. In Washington, most lynx occur above 4,100 ft (1,250 m), and they select Engelmann spruce-subalpine fir forest cover types in winter. Lodgepole pine is the dominant tree species when this cover type is in its earlier successional stages, and when

lodgepole pine contains dense understories, it receives high use by lynx and hares. Lynx avoid Douglas fir and Ponderosa pine forests, openings, recent burns, and steep slopes.

(2) Snow conditions (winter conditions that provide and maintain deep fluffy snow for extended periods in boreal forest landscapes).

Protection of the PBFs for Canada Lynx may provide some benefit to Mount Rainier white-tailed ptarmigan by protecting snow conditions (from compaction, etc.), and subalpine forest landscapes that ptarmigan may go to in winter storms, although they will avoid the densely treed areas used by lynx and will use the openings avoided by lynx. However, forests and openings occur in a mosaic pattern, and some protections afforded for the lynx habitat may also protect openings used by Mount Rainier white-tailed ptarmigan.

5.0 CURRENT CONDITION

In this chapter, we assess the current condition of the Mount Rainier white-tailed ptarmigan in the terms of the 3Rs. To assess the resiliency of the ptarmigan, we identified analytical units and assigned condition categories to each analytical unit based on population needs and indicators.

5.1 Methodology

At an expert elicitation meeting held July 9, 2019, we defined two Representation Units (North and South) in which Mount Rainier white-tailed ptarmigan populations should occur in order to represent the full range of genetic, ecological, and geographic variation. A 30 mile (50 km) low-elevation gap between the Mount Rainier and Alpine Lakes population units separates these two representation units (Figure 3). The Southern Representation Unit is unique in that it is comprised of geographically isolated stratovolcanoes (Mount Rainier, Mount St. Helens, and Mount Adams) and the Goat Rocks and William O. Douglas wilderness areas. The Northern Representation Unit is unique in that it is comprised of the steep mountains and numerous glaciers common in the North Cascades, as well as two stratovolcanoes (Mount Baker and Glacier Peak).

We separated two contiguous population units (North Cascades East and North Cascades West) based on ecological differences in the habitat in these two areas (dry east side vs wet west side). Climate east of the Cascade crest transitions from maritime to continental with drier, warmer summers with lower soil moisture and colder winters (Littell et al. 2014, P. 115). Summer mean, minimum, and maximum temperatures are higher in the eastern Cascades; summer solar radiation is higher in the eastern Cascades; summer rainfall decreases moving from west to east across the Cascades; and vapor pressure deficits indicate that evaporation is highest in the eastern Cascades (Douglas and Bliss 1977, p 135). The dry, warm summers, gentler topography, lower winter snowfall, and more rapid snowmelt in the eastern Cascades provide vegetation community patterns that are in marked contrast to those to the west (Douglas and Bliss 1977, p. 141).

For each population unit, we assigned each indicator of each habitat “need” a current condition rating of Poor, Fair, Good, or Very Good, based on the definitions we applied to each indicator in Table 7. In many cases, we used our best professional judgement and communication with experts (generally WDFW for population indicators, and WDFW or land managers for habitat indicators). We used the Conservation Action Planning (CAP) Excel workbook tool (The Nature Conservancy 2010, entire) to roll up indicators for each population unit into ratings for each population need, ratings for categories of needs, and an overall resiliency score for the population unit as follows:

A numeric value was given to each Indicator: Very Good = 4.0, Good = 3.5, Fair = 2.5, and Poor = 1.0. We then averaged the values for each indicator to derive a single value for each population need. The need was then assigned a rating based on the average score for the indicators, using the following ranges:

- Poor: 1.0 - 1.745
- Fair: 1.75 - 2.995
- Good: 3.0 - 3.745
- Very Good: 3.75 - 4.0

The need ratings were then used to develop a single rating for each category of size, condition, or landscape context:

- If any Need = Poor, the Category is Poor.
- If any Need = Fair, the Category is Fair.
- If all Needs are all ranked Good and/or Very Good:
  - the Category is Good if the number of Good ratings are equal to or greater than the number of Very Good ratings.
  - the Category is Very Good if the number of Very Good ratings are greater than the number of Good ratings.

Each Category was used to develop an overall resiliency score for each population unit. The average of the Categories (using the same values as used for the Indicators: Very Good = 4.0, Good = 3.5, Fair = 2.5, and Poor = 1.0) yielded a score which was converted into a Resiliency Rating for each population unit. However, white-tailed ptarmigan cannot exist without habitat, so if both vegetation models projected no remaining habitat, we overrode the overall resiliency score with the size score (Poor).

Habitat area justification

Poor: <700 ha (1,730 ac). The size of alpine patches comprehensively surveyed for Vancouver Island white-tailed ptarmigan in 1997 varied from approximately 0.14 to 7.1 km^2 (36 - 1754 ac; KM unpublished info, in Jackson et. al 2015, p. 3). Thus, this size for a population represents only one patch. Baseline conditions indicate approximately 700 patches on Vancouver Island (the range of a subspecies, not just one population unit).

Fair: 700 ha to 1,620 ha (4,000 ac). Although ptarmigan have persisted on Vancouver Island, there is likely a demographic cost to utilizing smaller habitat patches. For instance, Vancouver Island white-tailed ptarmigan in the central island (with larger, more continuous patches of alpine) had higher breeding success and higher adult survival than birds in the more fragmented south island populations in 2011 (Jackson et al. 2015b). The subspecies is persisting, but at-risk. We expect this classifies as Fair (outside acceptable range of variation; requires human intervention) for a patch, but do not know how many patches are necessary for maintaining a population unit.

Good: 1,620 ha (4,000 ac) to 4,860 ha (12,000 ac). The smallest continuously occupied areas in New Mexico are 3,475 ac. We rounded this up to 4,000 ac as a minimum size for the Good category.

Very Good: >12,000 ac. We tripled the area for Good.

5.2 Uncertainty

We have several sources of uncertainty in our analysis of current condition:

- We generally have limited life history and habitat information for Mount Rainier white-tailed ptarmigan and are mainly drawing inferences from other subspecies of ptarmigan.
- We were not able to find measurements for many of the indicators we identified.
- The availability of climate microrefugia (snowbank edges, stream edges, cold air pockets) and their ability to mediate impacts of elevated temperatures are unknown. We expect the availability of microrefugia will decrease as the area of habitat area decreases. We also expect the availability of snowbank edges will be drastically reduced, if declining glacial area (NPS 2019; Riedell 2019) can be used as an index. Furthermore, as temperatures increase, only the microrefugia that provide the most cooling will be effective.
- Current distribution of Mount Rainier white-tailed ptarmigan, particularly in winter, is unknown.
- We know little about the effects of stressors on winter habitat because we have not identified where Mount Rainier white-tailed ptarmigan winter habitat occurs, local characteristics of winter habitat, or habitat quality.
- Synergistic effects (e.g., climate change and willow stem boring beetle, or climate change and recreation) are unknown.
- No demographic data are available for this subspecies. No vital rates are known for this subspecies.
- Projecting the area and distribution of the specific vegetation types shown in our current vegetation maps is the single most important need for predicting future changes in occupancy in the Mount Rainier white-tailed ptarmigan.

5.3 Assessment of Current Resiliency of Each Population

We estimated current resiliency of each population unit by assigning a rating category to indicators of each population need (Table 9). Individual indicators were averaged to create a score for each need, and each need summarized to create a rating for each category (Table 10).

Table 9. Current condition of demographic and habitat indicators for Mount Rainier white-tailed ptarmigan population resiliency. Demographic Needs, Habitat Needs, Indicators, and descriptions of indicator rating categories are from Table 7.

Population Unit	Category	Need	Indicator	Poor	Fair	Good	Very Good	Current Indicator Measurement	Current Rating
Mount Adams	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	**large gaps**	some gaps	small gaps with frequent connections	contiguous		Poor
		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	21.1-38C (70.1F - 100F)	**13.4-21C (56 -70F)**	7.3-13.3C (45 - 56F)	61.06+/-4.82	Good
		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	0-1	**0**	0	Very Good
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	<0.5	0.5 to 0.75	> 0.75 to 1	**>1**	see Glacier Melt table	Very Good
		Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalent (April 1)	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	58.71 +/- 7.36	Good
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy		
		Winter snow	Winter snow depth	too deep or too shallow	too deep or too shallow	slightly too deep or too shallow, but within historical	just right, Goldilocks		

						range of variation			
	Condition	Abundance of food resources	area of willow, alder or birch (winter)						Poor
		Abundance of food resources	Distance to water during breeding season	**>200m**	61-200m	11-60m	<10m		Poor
		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann		
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch		
		Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean (17.71-37.51)	**< 1 SD from historical mean (22.05-32.6)**	Pre-1970 levels		Good
		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	**Areas > 300m across**	Areas 200-300m across	Areas 100-199 m across	Areas < 100 m across		Poor
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	20-22% cover	**22-26% cover**		Very Good
		Cool microclimates	Glacial equilibrium line altitude		>300m above 1993-2018 mean levels	<=300m above 1993-2018 mean levels		Noisy Glacier P.O.R. (1993-2018) ELA is 1838m, Silver Glacier 2369m,	

								Sandalee Glacier 2205m, and North Klawatti Glacier 2175m all are+/-300m	
		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%		
		Population structure & recruitment	Nest success	< 30%	31% to 60%	61% to 75%	> 75%		
		Qualitative assessment of habitat quality	qualitative assessment of vegetation quality						Poor
	Size	Population size & dynamics	population growth (lambda)	<1	1	>1	>1		
		Population size & dynamics	Qualitative estimate of population size						
		Total area of modelled summer habitat	acres of alpine vegetation modelled from MC2	< 7 sq km (1730 ac)	1,731-4,000 ac	**4,000 - 12,000-ac**	> 12,000 ac	9,546 ac	Good
		Total area of modelled summer habitat	acres of alpine vegetation modelled from Transboundary Project (Krosby et al.)	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	Not modelled	
		Total area of summer habitat	mapped acres of "alpine" vegetation	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	16,222 ac	Very Good
		Total area of winter habitat	mapped acres of subalpine disturbance areas and subalpine parkland	< 7 sq km (1730 ac)	1,731-4,000 ac	**4,000 - 12,000-ac**	> 12,000 ac	4,427 ac	Good

Goat Rocks	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	small gaps with frequent connections	contiguous		
		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	21.1-38C (70.1F - 100F)	**13.4-21C (56 -70F)**	7.3-13.3C (45 - 56F)	67.54 F (19.74C) = RCP 4.5 68 +/- 2.58 = RCP 8.5	Good
		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	**0-1**	0	0.15	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	<0.5	0.5 to 0.75	**> 0.75 to 1**	>1	see Glacier Melt table	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalent (April 1)	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	37.01	Good
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy		
		Winter snow	Winter snow depth	too deep or too shallow	too deep or too shallow	slightly too deep or too shallow, but within historical range of variation	just right, Goldilocks		
	Condition	Abundance of food resources	area of willow, alder or birch (winter)						

		Abundance of food resources	Distance to water during breeding season	>200m	61-200m	11-60m	<10m		
		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann		
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch		
		Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	28.33	Good
		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	Areas > 300m across	Areas 200-300m across	Areas 100-199 m across	Areas < 100 m across		
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	20-22% cover	22-26% cover		
		Cool microclimates	Glacial equilibrium line altitude		>300m above 2019 levels	<=300m above 2019 levels		Noisy Glacier P.O.R. (1993-2018) ELA is 1838m, Silver Glacier 2369m, Sandalee Glacier 2205m, and North Klawatti Glacier 2175m all are+/-300m	
		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%		

		Population structure & recruitment	Nest success	< 30%	31% to 60%	61% to 75%	> 75%		
		Qualitative assessment of habitat quality	qualitative assessment of vegetation quality						Fair
	Size	Population size & dynamics	population growth (lambda)	<1	1	>1	>1		
		Population size & dynamics	Qualitative estimate of population size						
		Total area of modelled summer habitat	acres of alpine vegetation modelled from MC2	**< 7 sq km (1730 ac)**	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	0	Poor
		Total area of modelled summer habitat	acres of alpine vegetation modelled from Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	**4,000 - 12,000-ac**	> 12,000 ac	41.46 sq km; 10,123 ac by Transboundary Project	Good
		Total area of summer habitat	mapped acres of "alpine" vegetation	< 7 sq km (1730 ac)	1,731-4,000 ac	**4,000 - 12,000-ac**	> 12,000 ac	10,245.69 ac	Good
		Total area of winter habitat	mapped acres of subalpine disturbance areas and subalpine parkland	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	28,711 ac	
Mount Rainier	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	**small gaps with frequent connections**	contiguous		Good
		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	21.1-38C (70.1F - 100F)	**13.4-21C (56 -70F)**	7.3-13.3C (45 - 56F)	67.66 +/-3.16 F= RCP 4.5 68.1 +/-3.16 F=RCP 8.5	Good

		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	**0-1**	0	0.19	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	<0.5	0.5 to 0.75	**> 0.75 to 1**	>1	see Glacier Melt table	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalent (April 1)	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels		Good
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy		
		Winter snow	Winter snow depth	too deep or too shallow	too deep or too shallow	slightly too deep or too shallow, but within historical range of variation	just right, Goldilocks		
	Condition	Abundance of food resources	area of willow, alder or birch (winter)						Fair
		Abundance of food resources	Distance to water during breeding season	>200m	61-200m	**11-60m**	<10m		Good
		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann		
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch		

					after hatch				
		Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels		Good
		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	**Areas > 300m across**	Areas 200-300m across	Areas 100-199 m across	Areas < 100 m across		Poor
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	**20-22% cover**	22-26% cover		Good
		Cool microclimates	Glacial equilibrium line altitude		>300m above 2019 levels	<=300m above 2019 levels		Noisy Glacier P.O.R. (1993-2018) ELA is 1838m, Silver Glacier 2369m, Sandalee Glacier 2205m, and North Klawatti Glacier 2175m all are+/-300m	
		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%		
		Population structure & recruitment	Nest success	< 30%	31% to 60%	61% to 75%	> 75%		
		Qualitative assessment of habitat quality	qualitative assessment of vegetation quality						Fair

	Size	Population size & dynamics	population growth (lambda)	<1	1	>1	>1		
		Population size & dynamics	Qualitative estimate of population size						
		Total area of modelled summer habitat	acres of alpine vegetation modelled from MC2	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	19,092 ac	Very Good
		Total area of modelled summer habitat	acres of alpine vegetation modelled from Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	38,681 ac	Very Good
		Total area of summer habitat	mapped acres of "alpine" vegetation	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	47,959 ac	Very Good
		Total area of winter habitat	mapped acres of subalpine disturbance areas and subalpine parkland	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	15,101 ac	Very Good
Alpine Lakes	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	**small gaps with frequent connections**	contiguous		Good
		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	21.1-38C (70.1F - 100F)	**13.4-21C (56 -70F)**	7.3-13.3C (45 - 56F)	67.66-68.10 +/-3.16	Good
		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	**0-1**	0	0.26	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	<0.5	0.5 to 0.75	**> 0.75 to 1**	>1	see Glacier Melt table	Good

		Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalent (April 1)	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	43.3 +/- 16.5 for both RCP 4.5 and 8.5	Good
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy		
		Winter snow	Winter snow depth	too deep or too shallow	too deep or too shallow	slightly too deep or too shallow, but within historical range of variation	just right, Goldilocks		
	Condition	Abundance of food resources	area of willow, alder or birch (winter)						
		Abundance of food resources	Distance to water during breeding season	>200m	61-200m	**11-60m**	<10m		Good
		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann		
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch		
		Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	historical =27.91+/-4.95; RCP 4.5 = 27.14+/-5.45; RCP 8.5 = 27.32+/-5.52	Good

		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	Areas > 300m across	**Areas 200-300m across**	Areas 100-199 m across	Areas < 100 m across		Fair
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	**20-22% cover**	22-26% cover		Good
		Cool microclimates	Glacial equilibrium line altitude		>300m above 2019 levels	<=300m above 2019 levels		Noisy Glacier P.O.R. (1993-2018) ELA is 1838m, Silver Glacier 2369m, Sandalee Glacier 2205m, and North Klawatti Glacier 2175m all are+/-300m	
		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%		
		Population structure & recruitment	Nest success	< 30%	31% to 60%	61% to 75%	> 75%		
		Qualitative assessment of habitat quality	qualitative assessment of vegetation						Fair
	Size	Population size & dynamics	population growth (lambda)	<1	1	>1	>1		
		Population size & dynamics	Qualitative estimate of population size						

		Total area of modelled summer habitat	acres of alpine vegetation modelled from MC2	**< 7 sq km (1730 ac)**	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	0	Poor
		Total area of modelled summer habitat	acres of alpine vegetation modelled from Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	27,641 ac	Very Good
		Total area of summer habitat	mapped acres of "alpine" vegetation	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	78,203 ac	Very Good
		Total area of winter habitat		< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	57,431 ac	
North Cascades - west of crest	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	**small gaps with frequent connections**	contiguous		Good
		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	21.1-38C (70.1F - 100F)	**13.4-21C (56 -70F)**	7.3-13.3C (45 - 56F)	67.4	Good
		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	**0-1**	0	0.04	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	<0.5	0.5 to 0.75	**> 0.75 to 1**	>1	see Glacier Melt table	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalent (April 1)	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels		Good
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy		

		Winter snow	Winter snow depth	too deep or too shallow	too deep or too shallow	slightly too deep or too shallow, but within historical range of variation	just right, Goldilocks		
	Condition	Abundance of food resources	area of willow, alder or birch (winter)						Fair
		Abundance of food resources	Distance to water during breeding season	>200m	61-200m	**11-60m**	<10m		Good
		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann		
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch		
		Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels		Good
		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	Areas > 300m across	**Areas 200-300m across**	Areas 100-199 m across	Areas < 100 m across		Fair
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	**20-22% cover**	22-26% cover		Good
		Cool microclimates	Glacial equilibrium line altitude		>300m above 2019 levels	<=300m above 2019 levels		Noisy Glacier P.O.R. (1993-2018) ELA is 1838m, Silver Glacier	

								2369m, Sandalee Glacier 2205m, and North Klawatti Glacier 2175m all are+/-300m	
		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%		
		Population structure & recruitment	Nest success						
		Qualitative assessment of habitat quality	qualitative assessment of vegetation quality						Fair
	Size	Population size & dynamics	population growth (lambda)	<1	1	>1	>1		
		Population size & dynamics	Qualitative estimate of population size						
		Total area of modelled summer habitat	acres of alpine vegetation modelled from MC2	< 7 sq km (1730 ac)	1,731-4,000 ac	**4,000 - 12,000-ac**	> 12,000 ac	9546	Good
		Total area of modelled summer habitat	acres of alpine vegetation modelled from Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	160985	Very Good
		Total area of summer habitat	mapped acres of "alpine" vegetation	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	479930	Very Good
		Total area of winter habitat	mapped acres of subalpine disturbance	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	222036	Very Good

			areas and subalpine parkland						
North Cascades - east of crest	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	**small gaps with frequent connections**	contiguous		Good
		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	21.1-38C (70.1F - 100F)	**13.4-21C (56 -70F)**	7.3-13.3C (45 - 56F)	66.8	Good
		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	**0-1**	0	0.1	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	<0.5	0.5 to 0.75	**> 0.75 to 1**	>1	see Glacier Melt table	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalent (April 1)	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels		Good
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy		
		Winter snow	Winter snow depth	too deep or too shallow	too deep or too shallow	slightly too deep or too shallow, but within historical range of variation	just right, Goldilocks		
	Condition	Abundance of food resources	area of willow, alder or birch (winter)						

		Abundance of food resources	Distance to water during breeding season	>200m	**61-200m**	11-60m	<10m		Fair
		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann		
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch		
		Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels		Good
		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	Areas > 300m across	Areas 200-300m across	**Areas 100-199 m across**	Areas < 100 m across		Good
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	20-22% cover	22-26% cover		
		Cool microclimates	Glacial equilibrium line altitude		>300m above 2019 levels	<=300m above 2019 levels		Noisy Glacier P.O.R. (1993-2018) ELA is 1838m, Silver Glacier 2369m, Sandalee Glacier 2205m, and North Klawatti Glacier 2175m all are+/-300m	
		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%		

		Population structure & recruitment	Nest success						
		Qualitative assessment of habitat quality	qualitative assessment of vegetation quality						Very Good
	Size	Population size & dynamics	population growth (lambda)	<1	1	>1	>1		
		Population size & dynamics	Qualitative estimate of population size						
		Total area of modelled summer habitat	acres of alpine vegetation modelled from MC2	**< 7 sq km (1730 ac)**	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	0	Poor
		Total area of modelled summer habitat	acres of alpine vegetation modelled from Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	97,113 ac	Very Good
		Total area of summer habitat	mapped acres of "alpine" vegetation	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	221,555 ac	Very Good
		Total area of winter habitat	mapped acres of subalpine disturbance areas and subalpine parkland	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	**> 12,000 ac**	1,101,266 ac	Very Good
Mount St. Helens	Size	Total area of modelled summer habitat	acres of alpine vegetation modelled from MC2					0	Poor
		Total area of summer habitat	mapped acres of "alpine" vegetation					4,681 ac	Good

		Total area of winter habitat	mapped acres of subalpine disturbance areas and subalpine parkland					14 ac	Poor
William O. Douglas	Size	Total area of modelled summer habitat	acres of alpine vegetation modelled from MC2					0	Poor
		Total area of summer habitat	mapped acres of "alpine" vegetation					4,453 ac	Good
		Total area of winter habitat	mapped acres of subalpine disturbance areas and subalpine parkland					17,350 ac	Very Good

The current resiliency rating summarized across all indicators, needs, and categories (as described in the methodology section) is currently Good for all population units, except the Mount Adams population unit, which is Fair. (Table 10).

Table 10. Current (2019) resiliency rating for each Mount Rainier white-tailed ptarmigan population unit. Ratings for each "need" are the average of rating scores for individual indicators in Table 7.

	Landscape[6] Context	Condition	(Habitat) Size	Resiliency Rating
Mount Adams	Poor	Poor	Good	**Fair**
Goat Rocks	Good	Fair	Fair	**Fair**
Mount Rainier	Good	Fair	Very Good	**Good**
Alpine Lakes	Good	Fair	Fair	**Fair**
North Cascades - west of crest	Good	Fair	Very Good	**Good**
North Cascades - east of crest	Good	Good	Fair	**Good**
Mount St. Helens (extirpated)	-	-	Poor	**Poor**
William O. Douglas (occupancy unknown)	-	-	Poor	**Poor**

5.3 Current Species Resiliency, Redundancy and Representation

We estimate resiliency is Good for three populations, Fair for three population units, and Poor for two population units. However, we were unable to obtain values for many of the indicators of resiliency (Table 7).

Redundancy is limited. The Mount St. Helens population unit is extirpated, and the William O. Douglas population unit contains potential habitat, but we have no records of white-tailed

[6] Ratings for the categories of landscape context, condition, and size reflect the lowest ratings of the individual "needs" in each category; and the overall resiliency rating for each population unit are the average of scores for the categories of landscape context, condition, and size.

ptarmigan in the area and consider occupancy unknown for this population unit. Therefore, we consider the redundancy of Mount Rainier white-tailed ptarmigan to be six population units overall. The Southern Representation Unit contains three extant, one extirpated, and one population unit of unknown occupancy status. Only one of these has Good resiliency. Three extant population units occur in the Northern Representation Unit. If a catastrophic event were to occur the either representation unit, two population units would remain, which is the lowest level of redundancy possible, and increases risk for the subspecies should a catastrophic event occur, such as another volcanic eruption.

Representation is characterized by the two geographic areas: the South Representation Unit and the North Representation Unit. Multiple Mount Rainier white-tailed ptarmigan population units occur in each representation unit, so representation appears Good. However, the population units in the Southern Representation Unit are isolated by large areas of forest or other gaps in habitat, and each population unit is small. Expert opinion indicates the number of birds in each population unit of the Southern Represenation Unit is also likely to be low, with the exception of the Mount Rainier population unit. Therefore representation is unequal between the two representation units.

6.0 SPECIES' FUTURE CONDITION AND STATUS

6.1 Methodology

To assess future conditions, we developed four future scenarios. The scenarios are based on two climate scenarios and two management scenarios. To evaluate these scenarios, we repeated the assessment of resiliency, as for current condition, using a CAP Excel workbook for each scenario, but altered the values of the indicators to reflect our best projection for how those indicators would respond to climate change and other stressors, as well as positive influences from management actions. For these assessments, we only used indicators for which we had climate change projections for future values, or for which we had qualitative information (e.g., expectations that recreation levels will increase) to project changes in the severity or scope of stress.

The IPCC identifies various greenhouse gas Representative Concentration Pathways (RCPs), which take into account different scenarios of greenhouse gas emissions, atmospheric concentrations, and land use likely to unfold in the 21st century. The IPCC characterizes several potential scenarios including RCP 4.5, an intermediate emissions scenario where atmospheric CO_2 concentrations are expected to equal approximately 650 ppm after the year 2100, and RCP 8.5, high emissions scenario where emissions sharply increase to approximately 1,370 ppm CO_2 after the year 2100. For comparison, current atmospheric CO_2 concentrations are around 400 ppm (IPCC 2014, p. 57). For the purposes of analyzing future conditions for the Mount Rainier white-tailed ptarmigan, we considered one intermediate scenario that assumes moderate cuts are made to emissions (RCP 4.5), and one high emissions scenario that assumes no deviation from the current emissions trajectory (RCP 8.5). Under current regulatory frameworks, general consensus is that emissions are currently tracking the RCP 8.5 scenario, and will not likely change unless new regulations or agreements are implemented. These emissions scenarios were chosen because they frame the most likely high and low boundaries of future greenhouse gas emissions. We use these two future emissions scenarios because after the middle of this century (2040-2069) (approximately 20-50 years), projections from these two models diverge due to uncertainty; future climate response to global warming increases with time from the present (IPCC 2014, p. 59). By presenting the projected effects on Mount Rainier white-tailed ptarmigan using both climate models, we enable decision makers to make their best judgement about which climate model they expect is most likely to occur in the foreseeable future, and evaluate the risk of underestimating or overestimating projected climate change effects. However, the latest date for which USGS data was available was 2069, and differences between the two scenarios are minimal by 2069.

We estimated area of alpine vegetation from the MC2 vegetation model, a Global Dynamic Vegetation Model that simulates vegetation type, plant growth and associated biogeochemical cycles, as well as their response to natural wildfires (Bachelet et al. 2015, entire). MC2 is based on the RCP 4.5 or RCP 8.5 scenarios (Bachelet et al., 2015, entire; Sheehan et al. 2015, entire). We also estimated area of alpine vegetation from Biome climatic niche models based on three earlier global climate projections (CGCM3 1 A2 2090, Hadley A2 2090, and Consensus A2 2090). These models were used to project alpine area (and other vegetation type areas) for the Transboundary Connectivity Project (Krosby et al. 2016, entire, based on the projections supplied by Rehfeldt et al. 2012). We downloaded projections of alpine area and subalpine area from Data Basin and clipped them to Mount Rainier white-tailed ptarmigan population boundaries. Alpine area is our most important and reliable indicator of resiliency, and alpine area from the NPS and Landfire vegetation maps provides our most reliable and important measure of current population resiliency. We report subalpine area for each Population Unit but did not use it as an indicator of future resilience because this measure does not differentiate between subalpine forests (which are not suitable for Mount Rainier white-tailed ptarmigan) and subalpine openings (suitable winter habitat). The acreages of these areas were included in the current condition tables for each population, but are not available for future scenarios. Development of future projections for winter habitat is the single most important information need for refining predictions of future population trends in the Mount Rainier white-tailed ptarmigan.

We analyzed the effects of climate change in areas that overlap with known Mount Rainier white-tailed ptarmigan populations through the middle of the century using data obtained from the Northwest Climate Toolbox, developed by members of the Applied Climate Science Lab at the University of Idaho (Pacific Northwest Climate Impacts Research Consortium, (CIRC, 2019). In addition to past and current data, the Northwest Climate Toolbox provides modeled future projections of climate and hydrology based on the effects of potential degrees of greenhouse gas emissions reported by the IPCC (IPCC, 2014, entire). Each future projection dataset we used for the purpose of analysis was a multi-model mean derived from multiple downscaled Coupled Model Intercomparison Project 5 (CMIP5) models. Though projections from individual models will vary for many reasons, the multi-model means often provide a good central estimate of the projected change (Pacific Northwest Climate Impacts Research Consortium (CIRC)). Data and projections obtained from the Northwest Climate Toolbox provide estimates of future conditions, but may not be entirely accurate for any given site or year.

6.2 Description of Future Scenarios

Scenario 1: GCM 4.5 with no management for white-tailed ptarmigan

The first scenario includes no population or land management actions designed to benefit white-tailed ptarmigan, but greenhouse gas emissions are regulated. This scenario includes effects of climate change on breeding and post-breeding habitat quality and quantity, summer temperature, and winter snow roosts. This scenario assumes recreation levels will increase throughout the range of the species, roads will be built in winter habitat, avalanches will continue to be triggered to protect roads, fire will be suppressed and grazing and hunting will continue at current or increased levels in British Columbia. We recorded projected temperature and moisture indictors from future projections by USGS and Glacial discharge estimates from Frans et al. (2018) in a CAP Excel workbook (TNC 2010, entire), which summarized scores across indicators for each need, and across needs for each category.

Scenario 2: GCM 8.5 with no management for white-tailed ptarmigan

This scenario uses the GCM 8.5 climate model to project potential effects on breeding and post-breeding quality and quantity, temperature, and snow roosts without additional regulation of emissions. This scenario includes no management for white-tailed ptarmigan. This is the more pessimistic climate change scenario, but is in line with current climate trajectories. This scenario includes effects of climate change on breeding and post-breeding habitat quality and quantity, summer temperature, and winter snow roosts. This scenario assumes recreation levels will increase throughout the range of the subspecies, roads will be built in winter habitat, avalanches will continue to be triggered to protect roads, fire will be suppressed and grazing and hunting will continue at current or increased levels in British Columbia. We recorded projected temperature and moisture indictors from future projections by USGS. We recorded glacial discharge estimates from Frans et al. (2018). We entered all scores into the CAP Excel workbook which summarized scores across indicators and categories. We conservatively input the largest acreage estimate from the three models included in the Transboundary Project projections.

Scenario 3: GCM 4.5 with managed recreation, roads, willow stem boring beetle, and microrefugia

This scenario uses the GCM 4.5 climate model to project temperature, moisture, and habitat area as described in Scenario 1. This scenario assumes recreation-related effects (e.g., habitat trampling, disturbance, pack stock grazing, helicopters, food waste), roads, and hunting are regulated to protect Mount Rainier white-tailed ptarmigan. We expect management of recreation, roads, and avalanche blasts could improve survival and fecundity of white-tailed ptarmigan. Management of recreation (e.g., snowmobile use), roads (likely in lower elevation winter habitat), avalanche blasts, elk populations, and willow stem boring beetle could reduce the rate of decline of suitable winter habitat. Similarly, management of off-trail recreation to reduce trampling, and creation of climate microrefugia (e.g., through shade or watering), could increase the amount of suitable breeding and post-breeding habitat compared to Scenario 1. However, we are not able to evaluate the potential improvement in demographic parameters because we have no baseline demographic information.

Scenario 4: GCM 8.5 with managed recreation, roads, willow stem boring beetle, and microrefugia

This scenario uses the GCM 8.5 climate model to project temperature, and moisture availability for alpine plants as described in Scenario 2. As with scenario 3, this scenario assumes recreation-related effects (e.g., habitat trampling, disturbance, horse grazing, helicopters, food waste), roads, elk populations, and hunting are regulated to protect Mount Rainier white-tailed ptarmigan. We expect management of recreation, roads, and avalanche blasts could improve survival and fecundity of white-tailed ptarmigan. However, we are not able to evaluate the potential improvement in demographic parameters because we have no baseline demographic information. Management of recreation (e.g., snowmobile use), roads (likely in lower elevation winter habitat), avalanche blasts, elk populations, and willow stem boring beetle could increase the amount of suitable winter habitat. Similarly, management of off-trail recreation to reduce trampling and creation of climate microrefugia (e.g., through shade or watering) could increase the amount of suitable breeding and post-breeding habitat compared to Scenario 2.

6.3 Uncertainty

We have several sources of uncertainty in our analyses of future condition:

- We generally have limited life history and habitat information for Mount Rainier white-tailed ptarmigan and are mainly drawing inferences from other subspecies of white-tailed ptarmigan.
- The availability of climate microrefugia (snowbank edges, stream edges, cold air pockets) and their ability to mediate impacts of elevated temperatures are unknown. We expect the availability and effectiveness of microrefugia will decrease as the area of habitat area decreases.
- Current distribution of Mount Rainier white-tailed ptarmigan, particularly in winter, is unknown.
- We know little about the effects of stressors on winter habitat because we have not identified where Mount Rainier white-tailed ptarmigan winter habitat occurs, local characteristics of winter habitat, or habitat quality.
- Synergistic effects (e.g., climate change and willow stem boring, or climate change and recreation) are unknown.
- No demographic data are available for this subspecies. No vital rates are known for this subspecies.
- Projecting the area and distribution of the specific vegetation types shown in our current vegetation maps is the single most important need for predicting future population trends in the Mount Rainier white-tailed ptarmigan.

6.4 Assessment of Future Condition of Each Population

Individual measures and ratings projected for each population need are presented in Table 11 for both future scenarios.

Table 11. Comparison of Mount Rainier white-tailed ptarmigan indicator ratings for each climate change scenario. Global Climate Models (GCM) are from Bachelet et.al (2015); definition of ratings categories are from Table 7.

Population Unit	Category	Need	Indicator	Rating Category				Scenario 1 GCM 4.5		Scenario 2 GCM 8.5	
				Poor	Fair	Good	Very Good	Indicator Measurement	Indicator Rating	Indicator Measurement	Indicator Rating
Mount Adams	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	small gaps with frequent connections	contiguous				
		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	21.1-38C (70.1F - 100F)	**13.4-21C (56 -70F)**	7.3-13.3C (45 - 56F)	63	Good	71.91	Fair
		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	0-1	**0**	0	Very Good	1.82	Fair
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	**<0.5**	0.5 to 0.75	> 0.75 to 1	>1	see Glacier melt table	Poor	see Glacier melt table	Poor
		Hydrologic regime - (timing, duration,	Snow water equivalant (April 1)	> 2 SD from histori	1-2 SD from histori	**< 1 SD from historical mean**	Pre-1970 levels	58.4 +/- 7.43	Good	56.24	Good

		frequency, extent)		cal mean	cal mean						
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy				
		Winter snow	Winter snow depth	too deep or too shallo w	too deep or too shallo w	slightly too deep or too shallow, but within historica l range of variation	just right, Goldilocks				
	Condition	Abundance of food resources	area of willow, alder or birch (winter)								
		Abundance of food resources	Distance to water during breeding season	>200 m	61-200m	11-60m	<10m				
		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann				
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch				

		Abundance of food resources	Soil moisture	> 2 SD from histori cal mean	1-2 SD from histori cal mean	**< 1 SD from historic al mean**	Pre-1970 levels	30 +/- 2.84	Good	30 +/-4.07	Good
		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	Areas > 300m acros s	Areas 200-300m across	Areas 100-199 m across	Areas < 100 m across				
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	20-22% cover	**22-26% cover**		Very Good		Very Good
		Cool microclimates	Glacial equilibrium line altitude		>300 m above 1993-2018 mean levels	<=300m above 1993-2018 mean levels		Noisy Glacier P.O.R. (1993-2018) ELA is 1838m, Silver Glacier 2369m, Sandalee Glacier 2205m, and North Klawatti Glacier 2175m all are+/-300m		Noisy Glacier P.O.R. (1993-2018) ELA is 1838m, Silver Glacier 2369m, Sandalee Glacier 2205m, and North Klawatti Glacier 2175m all are+/-300m	
		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%				
		Population structure & recruitment	Nest sucess	< 30%	31% to 60%	61% to 75%	> 75%				

	Size	Population size & dynamics	Number of adult males								
		Population size & dynamics	population growth (lambda)	<0	0	>0	>0				
		Total area of mapped summer habitat	acres of mapped habitat from NPS and Landfire data	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	no future maps		4773 ac	Good
		Total area of modelled summer habitat	acres of "alpine" vegetation modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	4.5 not modelled		not modelled, assume 0 based on Goat Rocks	Poor
		Total area of modelled summer habitat	acres of alpine tundra modelled by MC2	< 7 sq km (1730 ac)	1,731-4,000 ac	**4,000 - 12,000-ac**	> 12,000 ac	4,773 ac	Good		
		total area of modelled winter habitat	acres of subalpine modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	4.5 not modelled			
Goat Rocks	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	small gaps with frequent connections	contiguous				
		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	21.1-38C (70.1F - 100F)	**13.4-21C (56 -70F)**	7.3-13.3C (45 - 56F)	69.93 +/-2.58	Good	71.78	Fair

		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	**0-1**	0	0.27 +/- 0.49	Good	0.89	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	<0.5	0.5 to 0.75	**> 0.75 to 1**	>1		Good	>1	Very Good
		Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalant (April 1)	> 2 SD from histori cal mean	1-2 SD from histori cal mean	**< 1 SD from historic al mean**	Pre-1970 levels	37.37 +/1 12.18	Good	31	Good
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy				
		Winter snow	Winter snow depth	too deep or too shallo w	too deep or too shallo w	slightly too deep or too shallow, but within historica l range of variation	just right, Goldilocks				
	Condition	Abundance of food resources	area of willow, alder or birch (winter)								
		Abundance of food resources	Distance to water during breeding season	>200 m	61-200m	11-60m	<10m				

		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann				
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch				
		Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	27.19 +/1 5.48	Good	27.14	Good
		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	Areas > 300m across	Areas 200-300m across	Areas 100-199 m across	Areas < 100 m across				
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	20-22% cover	22-26% cover				
		Cool microclimates	Glacial equilibrium line altitude		>300 m above 2019 levels	<=300m above 2019 levels					
		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%				

		Population structure & recruitment	Nest sucess	< 30%	31% to 60%	61% to 75%	> 75%				
	Size	Population size & dynamics	Number of adult males								
		Population size & dynamics	population growth (lambda)	<0	0	>0	>0				
		Total area of mapped summer habitat	acres of mapped habitat from NPS and Landfire data	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	future not mapped		0	Poor
		Total area of modelled summer habitat	acres of "alpine" vegetation modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	4.5 not modelled		0	Poor
		Total area of modelled summer habitat	acres of alpine tundra modelled by MC2	**< 7 sq km (1730 ac)**	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	0 ac	Poor		
		total area of modelled winter habitat	acres of subalpine modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	4.5 not modelled			
Mount Rainier	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	small gaps with frequent connections	contiguous				

		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	21.1-38C (70.1F - 100F)	**13.4-21C (56 -70F)**	7.3-13.3C (45 - 56F)	66.03+/-5.31	Good	67.84	Good
		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	**0-1**	0	0.13	Good	0.53	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	<0.5	0.5 to 0.75	**> 0.75 to 1**	>1	0.75-1	Good	>1	Very Good
		Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalant (April 1)	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	49.75 (historical mean +/- 1 SD = 31.69-79.71)	Good	39.89	Good
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy				
		Winter snow	Winter snow depth	too deep or too shallow	too deep or too shallow	slightly too deep or too shallow, but within historical range of variation	just right, Goldilocks				
	Condition	Abundance of food resources	area of willow, alder or birch (winter)								

		Abundance of food resources	Distance to water during breeding season	>200 m	61-200m	11-60m	<10m				
		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann				
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch				
		Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	34.14	Good	34.14	Good
		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	Areas > 300m across	Areas 200-300m across	Areas 100-199 m across	Areas < 100 m across				
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	20-22% cover	22-26% cover				
		Cool microclimates	Glacial equilibrium line altitude		>300 m above 2019 levels	<=300m above 2019 levels					

		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%				
		Population structure & recruitment	Nest sucess	< 30%	31% to 60%	61% to 75%	> 75%				
	Size	Population size & dynamics	Number of adult males								
		Population size & dynamics	population growth (lambda)	<0	0	>0	>0				
		Total area of mapped summer habitat	acres of mapped habitat from NPS and Landfire data	< 7 sq km (1730 ac)	1,731-4,000 ac	334,000 - 12,000- ac	> 12,000 ac	future not mapped		9576	Good
		Total area of modelled summer habitat	acres of "alpine" vegetation modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000- ac	> 12,000 ac	4.5 not modelled		755 ac	Fair
		Total area of modelled summer habitat	acres of alpine tundra modelled by MC2	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000- ac	**> 12,000 ac**	14319	Very Good		
		total area of modelled winter habitat	acres of subalpine modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000- ac	> 12,000 ac	4.5 not modelled			
Alpine Lakes	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	small gaps with frequent	contiguous				

						connections					
		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	**21.1-38C (70.1F - 100F)**	13.4-21C (56 -70F)	7.3-13.3C (45 - 56F)	70.05 +/-3.16	Fair	71.91	Fair
		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	**0-1**	0	0.73	Good	1.82	Fair
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	<0.5	0.5 to 0.75	**> 0.75 to 1**	>1	0.75-1	Good	>1	Very Good
		Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalant (April 1)	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	43.3 +/- 16.5	Good	37.87	Good
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy				
		Winter snow	Winter snow depth	too deep or too shallow	too deep or too shallow	slightly too deep or too shallow, but within historical range of variation	just right, Goldilocks				

	Condition	Abundance of food resources	area of willow, alder or birch (winter)								
		Abundance of food resources	Distance to water during breeding season	>200 m	61-200m	11-60m	<10m				
		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann				
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch				
		Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	26.25+/-6.38; historical =27.91-4.95=23 (min)	Good	26.2	Good
		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	Areas > 300m across	Areas 200-300m across	Areas 100-199 m across	Areas < 100 m across				
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	20-22% cover	22-26% cover				
		Cool microclimates	Glacial equilibrium line altitude		>300 m above	<=300m above					

					2019 levels	2019 levels					
		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%				
		Population structure & recruitment	Nest sucess	< 30%	31% to 60%	61% to 75%	> 75%				
	Size	Population size & dynamics	Number of adult males								
		Population size & dynamics	population growth (lambda)	<0	0	>0	>0				
		Total area of mapped summer habitat	acres of mapped habitat from NPS and Landfire data	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	future not mapped		0	Poor
		Total area of modelled summer habitat	acres of "alpine" vegetation modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	4.5 not modelled		0	Poor
		Total area of modelled summer habitat	acres of alpine tundra modelled by MC2	**< 7 sq km (1730 ac)**	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	0 ac	Poor		
		total area of modelled winter habitat	acres of subalpine modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	4.5 not modelled			

North Cascades - west of crest	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	small gaps with frequent connections	contiguous				
		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	21.1-38C (70.1F - 100F)	**13.4-21C (56-70F)**	7.3-13.3C (45 - 56F)	69.35	Good	71.22	Fair
		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	**0-1**	0	0.52	Good	0.72	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	**<0.5**	0.5 to 0.75	> 0.75 to 1	>1	<0.5	Poor	<0.5	Poor
		Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalant (April 1)	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	55.64	Good	50.78	Good
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy				
		Winter snow	Winter snow depth	too deep or too shallow	too deep or too shallow	slightly too deep or too shallow, but within historical range	just right, Goldilocks				

						of variation					
	Condition	Abundance of food resources	area of willow, alder or birch (winter)								
		Abundance of food resources	Distance to water during breeding season	>200 m	61-200m	11-60m	<10m				
		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann				
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch				
		Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	28.17	Good	28.18	Good
		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	Areas > 300m across	Areas 200-300m across	Areas 100-199 m across	Areas < 100 m across				
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	20-22% cover	22-26% cover				

		Cool microclimates	Glacial equilibrium line altitude		>300 m above 2019 levels	<=300m above 2019 levels					
		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%				
		Population structure & recruitment	Nest sucess								
	Size	Population size & dynamics	Number of adult males								
		Population size & dynamics	population growth (lambda)	<0	0	>0	>0				
		Total area of mapped summer habitat	acres of mapped habitat from NPS and Landfire data	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	future not mapped		0	Poor
		Total area of modelled summer habitat	acres of "alpine" vegetation modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	4.5 not modelled		0	Poor
		Total area of modelled summer habitat	acres of alpine tundra modelled by MC2	**< 7 sq km (1730 ac)**	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	0 ac	Poor		
		total area of modelled winter habitat	acres of subalpine modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	4.5 not modelled			

North Cascades - east of crest	Landscape Context	Connectivity among communities & ecosystems	Connectivity between breeding, post-breeding, and winter habitat	large gaps	some gaps	small gaps with frequent connections	contiguous				
		Cool ambient temperatures	Maximum summer temperature	>38 degrees C (100F)	21.1-38C (70.1F - 100F)	**13.4-21C (56 -70F)**	7.3-13.3C (45 - 56F)	68.74	Good	71.22	Fair
		Cool ambient temperatures	Number of days above 30 degrees C	>3	1 to 3	**0-1**	0	0.26	Good	0.72	Good
		Hydrologic regime - (timing, duration, frequency, extent)	Glacier melt (discharge normalized to 1960-2010 mean)	**<0.5**	0.5 to 0.75	> 0.75 to 1	>1	<0.5	Poor	<0.5	Poor
		Hydrologic regime - (timing, duration, frequency, extent)	Snow water equivalant (April 1)	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	33.16	Good	50.78	Good
		Winter snow	Snow fluffiness	hard crust or wet	hard crust or wet	no hard crust, fluffy	no hard crust, fluffy				
		Winter snow	Winter snow depth	too deep or too shallow	too deep or too shallow	slightly too deep or too shallow, but within historical range	just right, Goldilocks				

						of variation					
	Condition	Abundance of food resources	area of willow, alder or birch (winter)								
		Abundance of food resources	Distance to water during breeding season	>200 m	61-200m	11-60m	<10m				
		Abundance of food resources	NDVI (early brood rearing: July 1)	below levels found by Wann	below levels found by Wann	levels found by Wann (2019)	above levels found by Wann				
		Abundance of food resources	phenology of peak NDVI in congruence with hatch	peak is > 42 days after hatch	peak is > 42 days after hatch	Peak is 0-42 days after hatch	Peak is 0-42 days after hatch				
		Abundance of food resources	Soil moisture	> 2 SD from historical mean	1-2 SD from historical mean	**< 1 SD from historical mean**	Pre-1970 levels	19.33	Good	28.18	Good
		Abundance of food resources	Unvegetated area of glacial forefront (not colonized by forage plants yet)	Areas > 300m across	Areas 200-300m across	Areas 100-199 m across	Areas < 100 m across				
		Cool microclimates	Cover or distribution of large boulders (breeding and post-breeding seasons)	< 20% cover	<20% cover	20-22% cover	22-26% cover				

		Cool microclimates	Glacial equilibrium line altitude		>300 m above 2019 levels	<=300m above 2019 levels					
		Population structure & recruitment	annual adult survival		<50%	50-75%	> 75%				
		Population structure & recruitment	Nest sucess								
	Size	Population size & dynamics	Number of adult males								
		Population size & dynamics	population growth (lambda)	<0	0	>0	>0				
		Total area of mapped summer habitat	acres of mapped habitat from NPS and Landfire data	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	future not mapped		0	Poor
		Total area of modelled summer habitat	acres of "alpine" vegetation modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	4.5 not modelled		415 ac	Poor
		Total area of modelled summer habitat	acres of alpine tundra modelled by MC2	**< 7 sq km (1730 ac)**	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	0	Poor		
		total area of modelled winter habitat	acres of subalpine modelled by Transboundary Project	< 7 sq km (1730 ac)	1,731-4,000 ac	4,000 - 12,000-ac	> 12,000 ac	4.5 not modelled			

Scenario 1

We averaged each indicator rating in Table 11 to create a single score for each species need, and subsequently summarized each attribute to obtain a single score for size, condition, and landscape context (Table 12). Vegetation projections using MC2 models indicate no units will have alpine tundra except 4,773 ac (1,932 ha) in the Mount Adams population unit (currently 9,546 ac (3,863 ha)) and 14,319 ac (5,795 ha) in the Mount Rainier population unit (currently 47,959 ac (19,408 ha)). We were not able to obtain bioclimatic niche vegetation models for SRES climate models equivalent to RCP 4.5. Bioclimatic variables remain good under this scenario. Two resilient population units in one representation unit would remain under this scenario.

Table 12. Resiliency ratings for Scenario 1: RCP 4.5, no management for ptarmigan, and projected at 2069 for vegetation and bioclimatic variables; projected at 2080 for glacial melt discharge. Ratings are for extant population units only.

Population Unit	Representation Unit	Landscape Context [1]	Condition	Size	Resiliency Rating
Mount Adams	South	Fair	Good	Good	**Good**
Goat Rocks	South	Good	Good	Poor	**Poor**
Mount Rainier	South	Good	Good	Very Good	**Good**
Alpine Lakes	North	Good	Good	Poor	Poor
North Cascades - west of crest	North	Fair	Good	Poor	Poor
North Cascades - east of crest	North	Fair	Good	Poor	Poor
Mount St. Helens	South	-	-	Poor	**Poor**
William O. Douglas	South	-	-	Poor	**Poor**

[1]Size is a measure of the area or abundance of the conservation target – in this case the area of habitat for each population unit. • Condition is a measure of the biological composition, structure and biotic interactions that characterize the occurrence – in this case physical and biological habitat features. • Landscape context is an assessment of the target's (population unit's) environment including ecological processes and regimes that maintain the target occurrence such as flooding, fire regimes

and many other kinds of natural disturbance, and connectivity such as species targets having access to habitats and resources or the ability to respond to environmental change through dispersal or migration.

Scenario 2

Under this scenario, the bioclimatic niche models project no breeding season habitat will remain for any population unit except for the Mount Rainier and North Cascades West population units. Additionally, the most optimistic model (Consensus A2 2090) estimates only 415 ac (168 ha) will remain in the North Cascades West population unit (Figure 9; Appendix D). This habitat area is considered Poor in our a priori description of species requirements, and therefore the size of this representation unit is Poor. However, the MC2 models project the size of alpine tundra in the Mount Adams population unit will be 4,773 ac (1,932 ha), just above our threshold for Good, but no habitat will remain in the two North Cascades population units. The two vegetation models average to a rating of Fair for the amount of habitat in the Mount Adams population unit. White-tailed ptarmigan cannot exist without habitat, therefore we expect all populations except for Mount Rainier and Mount Adams population units will be extirpated, and we overwrote averaged resiliency ratings to reflect the lack of habitat and subsequent extirpation. The Mount Adams population unit would not be resilient. As a result, under this scenario, Mount Rainier white-tailed ptarmigan will be represented in one representation unit by one resilient population unit, with no redundancy. If stochastic events (e.g. volcanic eruption), affected this one population unit, the subspecies would go extinct.

Table 13. Resiliency ratings for Scenario 2: RCP 8.5, no management for ptarmigan, and projected at 2069 for all indicators except Bioclimatic Niche vegetation models, which are projected at 2090.

Population Unit	Representation Unit	Landscape Context	Condition	Size	Resiliency Rating
Mount Adams	South	Fair	Good	Fair	**Fair**
Goat Rocks	South	Good	Good	Poor	Poor
Mount Rainier	South	Good	Good	Fair	**Good**
Alpine Lakes	North	Fair	Good	Poor	Poor
North Cascades - west of crest	North	Fair	Good	Poor	Poor
North Cascades - east of crest	North	Fair	Good	Poor	Poor
Mount St. Helens	South	-	-	Poor	Poor
William O. Douglas	South	-	-	Poor	Poor

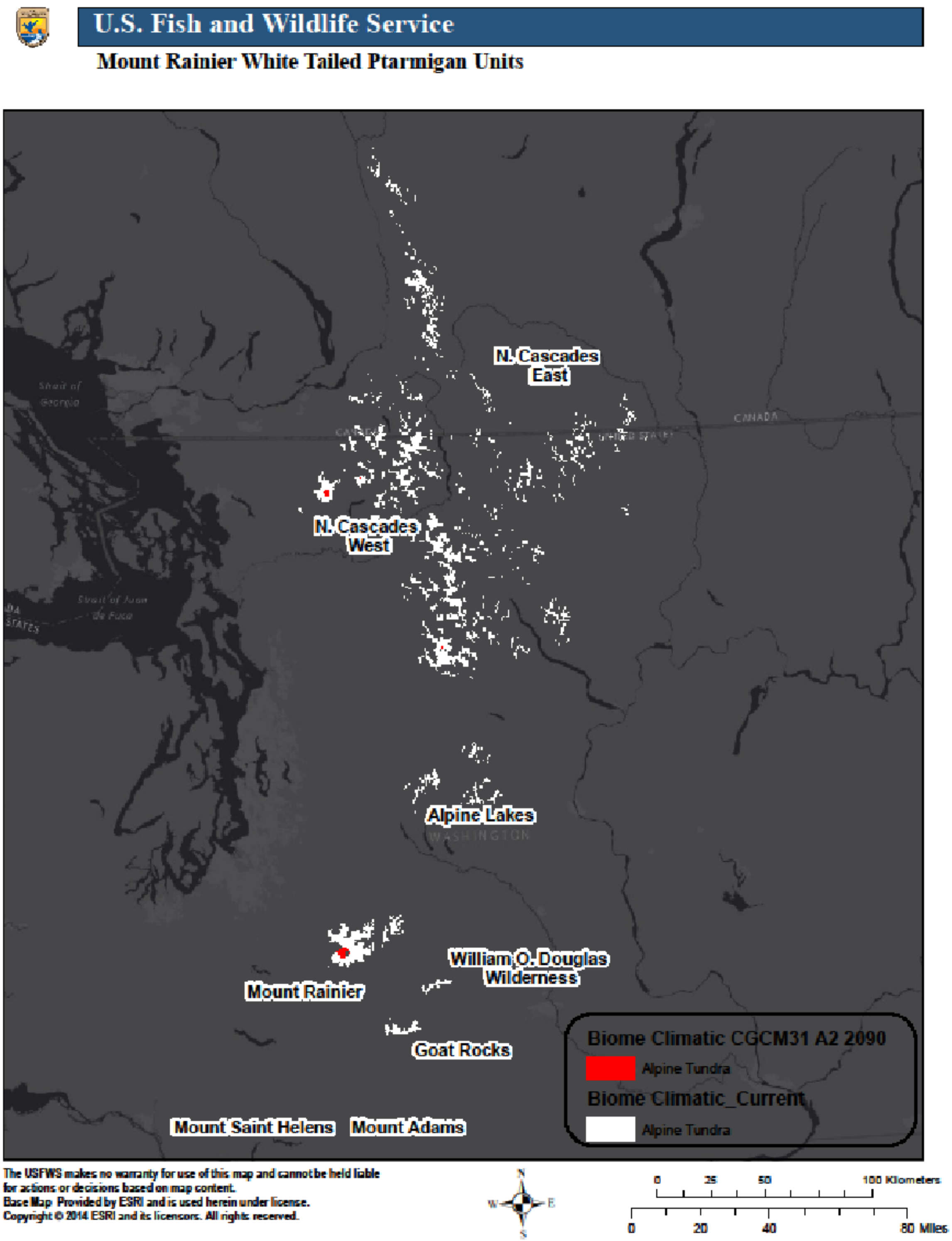


Figure 9. Breeding and post-breeding season habitat under current conditions and in the future under the Biome Climatic Niche Model (CGCM31A2 2090) as mapped by the Transboundary Project, data from DataBasin.org.

Scenario 3

As with Scenario 1, this scenario includes only the MC2 models for projected area of breeding and post-breeding habitat. Like Scenario 1, vegetation projections using MC2 models indicate no population units will have alpine tundra except 4,773 ac (1932 ha) in the Mount Adams population unit and 14,319 ac (5,795 ha) in the Mount Rainier population unit. We overwrote overall resiliency ratings to reflect this lack of habitat. We were not able to obtain bioclimatic niche vegetation models for SRES climate models equivalent to RCP 4.5. Bioclimatic variables remain good under this scenario. Two resilient population units in one representation unit would remain under this scenario. The resiliency rating is based on landscape context (hydrologic regimes, snow conditions, ambient temperatures, and connectivity between seasonal use areas), and condition (habitat indicators that describe the quality, but not quantity, of breeding and post-breeding habitat).

Table 14. Resiliency ratings for Scenario 3: RCP 4.5 and implementation of management actions for white-tailed ptarmigan.

Population Unit	Representation Unit	Landscape Context	Condition	Size	Resiliency Rating
Mount Adams	South	Fair	Good	Good	**Good**
Goat Rocks	South	Good	Good	Poor	**Poor**
Mount Rainier	South	Good	Good	Very Good	**Good**
Alpine Lakes	North	Good	Good	Poor	Poor
North Cascades - west of crest	North	Fair	Good	Poor	Poor
North Cascades - east of crest	North	Fair	Good	Poor	Poor
Mount St. Helens	South	-	-	Poor	**Poor**
William O. Douglas	South	-	-	Poor	**Poor**

Scenario 4

Under this scenario, bioclimatic niche models project no breeding season habitat will remain for any population unit except for the Mount Rainier and the North Cascades West population units. Additionally, the most optimistic model (Consensus A2 2090) estimates only 415 ac (168 ha) will remain in the North Cascades West population unit and only 755 ac (306 ha) will remain in the Mount Rainier population unit. This amount of habitat area is considered Poor in our a priori description of species requirements, and therefore the condition of this population unit would be Poor. MC2 models project no breeding season habitat will remain for any population unit except for the Mount Rainier (9,576 ac (3,875 ha)) and Mount Adams (4,773 ac (1,932 ha)) population units. This amount of habitat area is considered Good in our a priori descriptions. Taken together, the rating for size under this scenario is Fair for the Mount Rainier and Mount Adams population units, and Poor for the North Cascades West population unit.

However, this is the increased management scenario, so we assume federal land managers will make extensive efforts to ensure ptarmigans and their habitat are maintained in the North Cascades West population unit, despite the small amount of area. We project that all other population units will be extirpated because they will have no summer habitat; no amount of management could improve conditions. As a result, under this scenario, Mount Rainier white-tailed ptarmigan will be represented in one representation unit by one resilient population unit and another representation unit by one non-resilient population unit maintained by extensive habitat and population management. Redundancy across the subspecies' range will rely on just two population units (Mount Adams and North Cascades West), but there will be no redundancy within either representation unit. However, if a catastrophic event were to extirpate one population unit, one would remain.

Table 15. Resiliency ratings for Scenario 4: RCP 8.5 and implementation of management actions for white-tailed ptarmigan.

Population Unit	Representation Unit	Landscape Context	Condition	Size	Resiliency Rating
Mount Adams	South	Fair	Good	Fair	**Fair**
Goat Rocks	South	Good	Good	Poor	Poor
Mount Rainier	South	Good	Good	Good	**Good**
Alpine Lakes	North	Fair	Good	Poor	Poor
North Cascades - west of crest	North	Fair	Good	Poor	**Fair**
North Cascades - east of crest	North	Fair	Good	Poor	Poor

6.5 Species Future Resiliency, Redundancy and Representation

Comparison of all scenarios to current condition

Under Scenario 1, resiliency ratings are Fair, meaning they will require active management for persistence, for all population units except the Mount Adams and Mount Rainier population units. A minimum of one resilient population unit and a maximum of six resilient population units are expected under this scenario.

Under Scenario 2, the scenario representing the current climate change trajectory, resiliency ratings are Poor for all population units except the Mount Rainier population unit. Mount Rainier white-tailed ptarmigan would occupy one population unit across the range of the species. Mount Rainier white-tailed ptarmigan would be represented in only one representation unit - the South Representation Unit. The North Representation Unit would be extirpated. This represents a loss of five population units and one representation unit from current conditions. The risk from catastrophic and stochastic processes would be considerably greater under this scenario.

Scenario 3 is similar to Scenario 1. Because we do not know the resiliency of these population units, we cannot estimate redundancy or representation. We do expect resiliency, redundancy, and representation will be somewhere between current condition and Scenario 2. A minimum of one resilient population unit and a maximum of six resilient population units are expected under this scenario.

Scenario 4 is similar to Scenario 2, with the exception that management efforts may allow the population in the North Cascades West to persist. Resiliency ratings are Poor for all population units except the Mount Rainier and the North Cascades West population units. This represents a loss of four populations units. Mount Rainier white-tailed ptarmigan would occupy one resilient and one heavily managed population unit across the range of the subspecies. Mount Rainier white-tailed ptarmigan would be represented in both North and South Representation Units. The risk from catastrophic and stochastic processes would be considerably greater under this scenario.

Table 16. Comparison of all future climate scenarios to current condition of each Mount Rainier white-tailed ptarmigan population unit.

Population Unit	Representation Unit	Current Condition	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Mount Adams	South	**Fair**	**Good**	**Fair**	**Good**	**Fair**
Goat Rocks	South	**Fair**	**Poor**	Poor	**Poor**	Poor
Mount Rainier	South	**Good**	**Good**	**Good**	**Good**	**Good**
Alpine Lakes	North	**Fair**	Poor	Poor	Poor	Poor
North Cascades - west of crest	North	**Good**	Poor	Poor	Poor	**Fair**
North Cascades - east of crest	North	**Good**	Poor	Poor	Poor	Poor
Mount St. Helens	South	**Poor**	**Poor**			
William O. Douglas	South	**Poor**	**Poor**			

7.0 SYNTHESIS

There have been no studies conducted on distribution, demographics, or habitat selection of Mount Rainier white-tailed ptarmigan. Based on one observational study, some information from banded birds, anecdotal observations, and information from other subspecies of white-tailed ptarmigan, Mount Rainier white-tailed ptarmigan are expected to require moist alpine vegetation and low ambient temperatures in the breeding and post-breeding seasons, and subalpine openings with exposed forage and snow roosting sites in winter. The primary threats to white-tailed ptarmigan include physiological stress due to elevated temperatures, reduced availability of moist alpine vegetation and associated insects, and loss of snow cover for climate microrefugia and camouflage, and most importantly, outright loss of breeding and post-breeding habitat as a result of changes in precipitation, wind, and temperature resulting from climate change. Loss of habitat is expected to cause extirpation of the smaller, lower elevation, and more southern population units. Under the GCM 8.5 scenario, the Mount Rainier white-tailed ptarmigan will be extirpated in all but one population unit by the end of the century. Projections for alpine habitat loss are supported by projections of altered hydrologic regimes in upper basins, and projections for subalpine habitat loss are supported by current and predicted future infill of subalpine meadows. Management actions that create microrefugia, control other threats (e.g., subalpine roads, alpine recreation), or reduce synergistic effects, will reduce the impact of climate change on Mount Rainier white-tailed ptarmigan populations.

We recommend the following for a future Mount Rainier white-tailed ptarmigan status assessment (not necessarily in order of importance):

1. Conduct basic research on the distribution, abundance, and habitat use patterns of Mount Rainier white-tailed ptarmigan, particularly during winter. One or two years of data would answer some of the most basic questions that are limiting the usefulness of this current species status assessment.
2. Once distribution information is available, overlay this information with potential stressors including roads, ski areas, other infrastructure, elk winter habitat, etc.
3. Work with partners to obtain measures for indicators with missing information in the workbooks for current and future condition scenarios. In particular, obtain future projections for subalpine openings, or other vegetation types as identified in winter habitat studies.
4. Work with vegetation ecologists to model the upslope migration of treeline and distribution of alpine vegetation communities projected with climate change scenarios RCP 4.5 and RCP 8.5. This may be possible with existing information.
5. Evaluate the future projections of summer soil water deficits projected to occur with climate change. This analysis is possible with existing information.
6. Conduct a climate envelope model based on observational data, biogeoclimatic variables, and the vegetation data layers we have created for this species status assessment. Jackson et al. (2015) conducted a similar model for the Vancouver Island white-tailed ptarmigan; their methods could be used or adapted for the Mount Rainier white-tailed ptarmigan with existing information.
7. Conduct research on the impacts of recreation and human presence on white-tailed ptarmigan, including effects of corticosteroid levels, productivity, spatial/temporal use

patterns, health, time spent vigilant, impacts on habitat use patterns, and impacts to reproductive success and adult survival.

8. Conduct finer resolution genetic sampling to determine whether Mount Rainier white-tailed ptarmigan and northern white-tailed ptarmigan represent distinct groups and, if so, the locations of the boundaries.
9. Conduct a taxonomic review of the species if #8 determines it is warranted.

Literature Cited

Aldrich, J. 1963. Geographic orientation of American Tetraonidae. The Journal of Wildlife Management 27:528-545.

Aldrich, J., and A. Duvall. 1955. Distribution of American Gallinaceous game birds. 34 pp.

American Ornithologists' Union. 1957a. Check-list of North American Birds. 5th edition. The Lord Baltimore Press. Baltimore, MD, USA. 691.

--------1957b. Check-list of North American Birds - Intro, Order Galliformes, index. 5th edition. The Lord Baltimore Press. Baltimore, MD, USA. i-691.

--------1998. Check-list of North American birds; Order Galliformes through Order Charadriiformes. Pages i-216 *in* Check-list of North American Birds. Allen Press, Lawrence, KS, USA.

B.C. Conservation Data Centre. 1996 Species Summary: *Lagopus leucura*. Accessed Aug 19, 2019.

Bachelet, D., K. Ferschweiler, T. J. Sheehan, B. M. Sleeter, and Z. Zhu. 2015. Projected carbon stocks in the conterminous USA with land use and variable fire regimes. Global Change Biology 21:4548-4560. Bailey, A. 1927. Notes on the birds of Southeastern Alaska (continued). The Auk 44:184-205.

Benson, D., and M. Cummins. 2011. Move, adapt or die: *Lagopus leucura* changes in distribution, habitat and number at Glacier National Park, Montana. Pages 237-246 *in* R. Watson, T. Cade, M. Fuller, G. Hunt, and E. Potapov, editors. Gyrfalcons and Ptarmigan in a changing world, Volume 1. The Peregrine Fund, Boise, Idaho.

Benson, D. 2002. Low extra-pair paternity in white-tailed ptarmigan. American Ornithological Society 104:192-197.

Bird, J. P., R. Martin, H. R. Akçakaya, J. Gilroy, I. J. Burfield, S. T. Garnett, A. Symes, J. Taylor, Ç H. Şekercioğlu, and S. H. M. Butchart. 2020. Generation lengths of the world's birds and their implications for extinction risk. Conservation Biology <https://doi.org/10.1111/cobi.13486>.

Björk, R. G., and U. Molau. 2007. Ecology of Alpine Snowbeds and the Impact of Global Change. Arctic, Antarctic, and Alpine Research 39:34-43.

Bohling, J. 2019. Review of Langin et al. (2018) Characterizing range-wide divergence in an alpine-endemic bird: a comparison of genetic and genomic approaches. Conservation Genetics 19: 1471-1485. Unpublished report. 18 September, 2019. 4 pp.

Bowker, J.M., and A.E. Askew. 2012. U.S. Outdoor Recreation Participation Projections to 2060. Pages 105-124 *in* Cordell, H. K. ed. 2012. Outdoor Recreation Trends and Futures: A technical document supporting the Forest Service 2010 Resources Planning Act

Assessment. Gen. Tech. Rep. SRS-150. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station..

Brantley, S., and B. Meyers. 1997. Mount St. Helens - From the 1980 Eruption to 2000. U.S. Geological Survey. 2 pp.

Braun, C.E., K. Martin, and L.A. Robb. 1993. White-tailed ptarmigan (*Lagopus leucurus*) *in* A. Poole and F. Gill, editors. The birds of North America, Number 68. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C., 24 pp.

Braun, C.E., R.W. Hoffman, and G.E. Rogers. 1976. Wintering areas and winter ecology of white-tailed ptarmigan in Colorado. Special Report 38. Colorado Division of Wildlife, Fort Collins, CO, USA.

Braun, C., K. Martin, and L. Robb. 2011. White-tailed ptarmigan *in* A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C.. Available online at <www.bna.birds.cornell.edu/bna/.../introduction>. Accessed May 16, 2019.

Braun, C., and G. Rogers. 1971. The white-tailed ptarmigan in Colorado. Colorado Division of Game, Fish and Parks. Project W-37R. Technical publication number twenty-seven. Braun, C., and R. Schmidt. 1971. Effects of snow and wind on wintering populations of white-tailed ptarmigan in Colorado. Pages 1-13 *in* Snow and Ice Symposium. Iowa Cooperative Wildlife Research Unit, Iowa State University, Ames, IA, USA.

Braun, C., D. Stevens, K. Giesen, and C. Melcher. 1991. Elk, white-tailed ptarmigan and willow relationships: A management dilemma in Rocky Mountain National Park. Pp. 74-85 *in* Trans. 56th N. A. Wildlife and Natural Resources Conference.

Braun, C. 1969. Population dynamics, habitat, and movements of white-tailed ptarmigan in Colorado. PhD Dissertation, Colorado State University. Fort Collins, Colorado. Braun, C. E., and G. T. Wann. 2017. Historical Occurrence of white-tailed ptarmigan in Wyoming. Western North American Naturalist 77:204-211.

Braun, C. 2019. Grouse Inc., Tucson, AZ. Peer review of draft Species Status Assessment for the Mount Rainier White-tailed Ptarmigan. 23 December, 2019.

Broberg, C. L., J. H. Borden, and L. M. Humble. 2002. Distribution and abundance of *Cryptorhynchus lapathi* on Salix spp. in British Columbia. Canadian Journal of Forest Research 32:561-568.

Canaday, B. B., and R. W. Fonda. 1974. The Influence of Subalpine Snowbanks on Vegetation Pattern, Production, and Phenology. Bulletin of the Torrey Botanical Club 101:340-350. Cansler, C. A., D. McKenzie, and C. B. Halpern. 2018. Fire enhances the complexity of forest structure in alpine treeline ecotones. Ecosphere 9:e02091-n/a. <https://onlinelibrary.wiley.com/doi/abs/10.1002/ecs2.2091>.

Cassidy, K. M., M. R. Smith, C. E. Grue, K. M. Dvornich, J. E. Cassady, K. R. McAllister, and R. E. Johnson. 1997. GAP anlaysis of Washington State: an evaluation of the protection of biodiversity in volume 5 Washington State gap analysis- final report.

Casola, J. H., L. Cuo, B. Livneh, D. P. Lettenmaier, M. T. Stoelinga, P. W. Mote, and J. M. Wallace. 2009. Assessing the Impacts of Global Warming on Snowpack in the Washington Cascades. Journal of Climate 22:2758-2772.

Chestnut, T. 2019. Comments in meeting notes from Mount Rainier white-tailed ptarmigan species status assessment meeting held September 10, 2019.

-------- 1963. Habitat and population dynamics of white-tailed ptarmigan in Montana. The Journal of Wildlife Management 27:684-699.

Clarke, J. 2010. White-tailed ptarmigan food calls enhance chick diet choice: learning nutritional wisdom? Animal Behaviour 79:25-30.

Clarke, J., and R. Johnson. 1990. Biogeography of white-tailed ptarmigan (*Lagopus leucurus*): Implications from an introduced population in the Sierra Nevada. Journal of Biogeography 17:649-656.

-------- 1992. The influence of spring snow depth on white-tailed ptarmigan breeding success in the Sierra Nevada. The Condor 94:622-627.

-------- 2005. Comparisons and contrasts between the foraging behaviors of two white-tailed ptarmigan (*Lagopus leucurus*) populations, Rocky Mountains, Colorado, and Sierra Nevada, California, U.S.A. Arctic, Antarctic, and Alpine Research 37:171-176.

Clements, J. F., T. S. Schulenberg, M. J. Iliff, S. M. Billerman, T. A. Fredericks, B. L. Sullivan, and C. L. Wood. 2019. The eBird/Clements Checklist of Birds of the World: v2019. Downloaded from https://www.birds.cornell.edu/clementschecklist/download/ on September 24, 2019 Conservation Measures Partnership. 2013. The Open Standards for the Practice of Conservation, v. 3. Available at <http://www.conservationmeasures.org/>. 47 pp.

Dick, K. A. 2013. Glacier Change in the North Cascades, Washington: 1900-2009. Master's Thesis. Portland State University. Portland, Oregon.

Donaldson, D. 2018. 2018 Hunting Regulations for British Columbia, Canada.

Douglas, G. W. 1972. Subalpine Plant Communities of the Western North Cascades, Washington. Arctic and Alpine Research 4:147-166.

Douglas, G. W., and L. C. Bliss. 1977. Alpine and High Subalpine Plant Communities of the North Cascades Range, Washington and British Columbia. Ecological Monographs 47:113-150.

eBird. 2017 eBird: An online database of bird distribution and abundance [web application]. eBird, Cornell Lab of Ornithology, Ithaca, New York. <http://www.ebird.org>. Accessed November 18, 2019.

Elsner, M., L. Cuo, N. Voisin, J. Deems, A. Hamlet, J. Vano, K. Mickelson, S. Lee, and D. Lettenmaier. 2010. Implications of 21st century climate change for the hydrology of Washington State. Climatic Change 102:225-260. Evans, R. D., and R. W. Fonda. 1990. The influence of snow on subalpine meadow community pattern, North Cascades, Washington. Canadian Journal of Botany 68:212-220. Fagre, D. B., D. L. Peterson, and A. E. Hessl. 2003. Taking the Pulse of Mountains: Ecosystem Responses to Climatic Variability. Climatic Change 59:263-282.

Fedy, B., K. Martin, C. Ritland, and J. Young. 2008. Genetic and ecological data provide incongruent interpretations of population structure and dispersal in naturally subdivided populations of white-tailed ptarmigan (*Lagopus leucura*). Molecular Ecology 17:1905-1917.

Fedy, B., and K. Martin. 2011. The Influence of Fine-Scale Habitat Features on Regional Variation in Population Performance of Alpine white-tailed ptarmigan. The Condor 113:306-315.

Franklin, J. F., William H. Moir, George W. Douglas, and Curt Wiberg. 1971. Invasion of Subalpine Meadows by Trees in the Cascade Range, Washington and Oregon. Arctic and Alpine Research 3:215-224. Franklin, J. R., and C. T. Dyrness. 1988. Natural vegetation of Oregon and Washington. Oregon State University Press. Portland, Oregon. 1-452.

Frans, C., E. Istanbulluoglu, D. P. Lettenmaier, A. G. Fountain, and J. Riedel. 2018. Glacier Recession and the Response of Summer Streamflow in the Pacific Northwest United States, 1960–2099. Water Resources Research 54:6202-6225.

Frederick, G., and R. Gutierrez. 1992. Habitat use and population characteristics of the white-tailed ptarmigan in the Sierra Nevada, California. The Condor 94:889-902.

Furniss, M. 1972. Poplar and Willow Borer. Forest Pest Leaflet 5 pp.

Giesen, K., and C. Braun. 1979. Nesting behavior of female white-tailed ptarmigan in Colorado. Condor 81:215-217.

-------- 1992. Winter home range and habitat characteristics of white-tailed ptarmigan in Colorado. The Wilson Bulletin 104:263-272.

Giesen, K., C. Braun, and T. May. 1980. Reproduction and nest-site selection by white-tailed ptarmigan in Colorado. The Wilson Bulletin 92:188-199.

Giesen, K. M., and C. E. Braun. 1993. Natal dispersal and recruitment of juvenile white-tailed ptarmigan in Colorado. Journal of Wildlife Management 57:72-77.

Gray, C. E. 2019. Regional Modeling of the Glaciers of the North Cascades Mountains, Washington, USA. PhD Dissertation, Portland State University. Portland, Oregon. 96 pp. Hamlet A.F., Mote P.W, Clark M.P., Lettenmaier D.P., 2005: Effects of temperature and precipitation variability on snowpack trends in the western U.S., J. of Climate, 18 (21):4545-4561.

Hannon, E., and J. Brown. 2017. Poplar and Willow Borer. 7 pp.

Hannon, S., and K. Martin. 2006. Ecology of juvenile grouse during the transition to adulthood. Journal of Zoology 269:422-433.

Hanski, I. 1982. Dynamics of Regional Distribution: The Core and Satellite Species Hypothesis. Oikos 38:210-221.

Harsch, M. A., P. E. Hulme, M. S. McGlone, and R. P. Duncan. 2009. Are treelines advancing? A global meta-analysis of treeline response to climate warming. Ecology Letters 12:1040-1049. Hendry, A. P., M. T. Kinnison, M. Heino, T. Day, T. B. Smith, G. Fitt, C. T. Bergstrom, J. Oakeshott, P. S. Jørgensen, M. P. Zalucki, G. Gilchrist, S. Southerton, A. Sih, S. Strauss, R. F. Denison, and S. P. Carroll. 2011. Evolutionary principles and their practical application. Evolutionary Applications 4:159-183. Herzog, P. 1980. Winter habitat use by white-tailed ptarmigan in Southwestern Alberta. Pages 159-162 *in* The Canadian Field-Naturalist. The Ottawa Field-Naturalists' Club, Ottawa, Canada.

Hoffman, R. 2006. White-tailed ptarmigan (*Lagopus leucura*): A technical conservation assessment.

-------- 2020. Peer review of Draft Mount Rainier White-tailed Ptarmigan Species Status Assessment. Received January 3, 2020.

Hoffman, R., and C. Braun. 1975. Migration of a wintering population of white-tailed ptarmigan in Colorado. The Journal of Wildlife Management 39:485-490.

-------- 1977. Characteristics of a wintering population of white-tailed ptarmigan in Colorado. The Wilson Bulletin 89:107-115.

Holtmeier, F., and G. Broll. 2005. Sensitivity and response of northern hemisphere altitudinal and polar treelines to environmental change at landscape and local scales. Global Ecology and Biogeography 14:395-410.

Iachetti, P., J. Floberg, G. Wilhere, K. Ciruna, D. Markovic, J. Lewis, M. Heiner, G. Kittel, R. Crawford, S. Farone, S. Ford, M. Goering, D. Nicolson, S. Tyler, and P. Skidmore. 2006. North Cascades and Pacific ranges ecoregional assessment, Volume 1 Report.

Imperio, S., R. Bionda, R. Viterbi, and A. Provenzale. 2013. Climate Change and Human Disturbance Can Lead to Local Extinction of Alpine Rock Ptarmigan: New Insight from the Western Italian Alps. PloS One 8:e81598. Available at <https://www.ncbi.nlm.nih.gov/pubmed/24260581>.

IPCC. 2014a. Climate change 2014: Impacts, adaptation, and vulnerability part A: Global and sectoral aspects, contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change.

-------- 2014b. Climate change 2014: Synthesis report, contribution of working groups I, II, and III to the fifth assessment report of the intergovernmental panel on climate change.

-------- 2019. Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.

Weyer (eds.)]. In press. Available at <https://report.ipcc.ch/srocc/pdf/SROCC_FinalDraft_FullReport.pdf>.

ITIS. 2019 *Lagopus leucura*. <www.itis.gov/servlet/SingleRpt/SingleRpt>. Accessed September 24, 2019 .

Jackson, M., E. Topp, S. Gergel, K. Martin, F. Pirotti, and T. Sitzia. 2015. Expansion of subalpine woody vegetation over 40 years on Vancouver Island, British Columbia, Canada. Canada Journal Forest Research 46:437-443.

Jackson, M. M., S. E. Gergel, and K. Martin. 2015a. Citizen science and field survey observations provide comparable results for mapping Vancouver Island white-tailed ptarmigan (*Lagopus leucura saxatilis*) distributions. Biological Conservation 181:162-172.

-------- 2015b. Effects of Climate Change on Habitat Availability and Configuration for an Endemic Coastal Alpine Bird. PloS One 10:1-20. <https://www.ncbi.nlm.nih.gov/pubmed/26529306>.

Johnson, R. 1968. Temperature regulation in the white-tailed ptarmigan, *Lagopus leucurus*. Comp. Biochem. Physiol. 24:1003-1014.

Johnston, A. N., J. E. Bruggeman, A. T. Beers, E. A. Beever, R. G. Christophersen, and J. I. Ransom. 2019. Ecological consequences of anomalies in atmospheric moisture and snowpack. Ecology 100:. Available at <https://doi.org/10.1002/ecy.2638>.

Jumpponen, A., H. Vare, K. G. Mattson, R. Ohtonen, and J. M. Trappe. 1999. Characterization of safe sites for pioneers in primary succession on recently deglaciated terrain. Journal of Ecology 87:98-105.

Jumpponen, A., K. Mattson, J. M. Trappe, and R. Ohtonen. 1998. Effects of Established Willows on Primary Succession on Lyman Glacier Forefront, North Cascade Range, Washington, U.S.A.: Evidence for Simultaneous Canopy Inhibition and Soil Facilitation. Arctic and Alpine Research 30:31-39.

Körner, C., and J. Paulsen. 2004. A world-wide study of high altitude treeline temperatures. Journal of Biogeography 31:713-732. Krosby, M., Michalak, J., Robbins, T.O., Morgan, H., Norheim, R., Mauger, G., Murdock, T. 2016. The Washington-British Columbia Transboundary Climate-Connectivity Project: Identifying climate impacts and adaptation actions for wildlife habitat connectivity in the transboundary region of Washington and British Columbia.

Krosby, M., Michalak, J., Robbins, T.O., Morgan, H., Norheim, R., Mauger, G., Murdock, T. 2016. The Washington-British Columbia Transboundary Climate-Connectivity Project: Identifying climate impacts and adaptation actions for wildlife habitat connectivity in the transboundary region of Washington and British Columbia

Kuk, M., 2019. E-mail correspondence from M. Kuk Wildlife Biologist, U.S. Forest Service. September 4, 2019.

Langin, K., C. Aldridge, J. Fike, S. Cornman, K. Martin, G. Wann, A. Seglund, M. Schroeder, C. Braun, D. Benson, B. Fedy, J. Young, S. Wilson, D. Wolfe, and S. Oyler-McCance. 2018.

Characterizing range-wide divergence in an alpine-endemic bird: a comparison of genetic and genomic approaches. Conservation Genetics 19:1471-1485.

Lankau, R., P. S. Jørgensen, D. J. Harris, and A. Sih. 2011. Incorporating evolutionary principles into environmental management and policy. Evolutionary Applications 4:315-325.

Ligon, J. S. 1961. Upland game birds; grouse and ptarmigan. Pages 84-95 *in* New Mexico birds and where to find them. The University of New Mexico Press, Albuquerque, NM.

Littell, J., C. Raymond, R. Rochefort, and S. Klein. 2014. Climate Change, Wildlife, and Wildlife Habitat in the North Cascade Range. Pages 113-176 *in* C. Raymond, D. Peterson, and R. Rochefort, editors. Climate Change Vulnerability and Adaptation in the North Cascades Region, Washington. General Technical Report, PNW-GTR-892. U.S.D.A. Forest Service, Portland, Oregon.

Luce, C. H., J. T. Abatzoglou, and Z. A. Holden. 2013. The Missing Mountain Water: Slower Westerlies Decrease Orographic Enhancement in the Pacific Northwest USA. Science 342:1360-1364.

Luce, C. 2019. Water, Infrastructure, and Climate Change in the Northwest. Pages no pagination *in* Pacific Northwest Regional Focus of the Fourth National Climate Assessment. U.S.D.A. Forest Service.

Martell, A. 2015. White-tailed ptarmigan. *in* P. Davidson, R. Cannings, A. Couturier, D. Lepage, and C. DiCorraco, editors. The atlas of the breeding birds of British Columbia, 2008-2012. Delta, B.C.

Martin, K., S. J. Hannon, and R. F. Rockwell. 1989. Clutch size variation and patterns of attrition in fecundity of willow ptarmigan. Ecology 70:1788-1799.

Martin, K., L. Robb, S. Wilson, and C. Braun. 2015. White-tailed ptarmigan, *Lagopus leucura*. Birds of North America.

Martin, K., L. A. Robb, S. Wilson, and C. E. Braun. 2020. (text last updated August 14, 2015). White-tailed ptarmigan - *Lagopus leucura* - Birds of the World. <https://birdsoftheworld.org/bow/species/whtpta1/cur/introduction>. Accessed 2020 May 15.

Martin, K., P. Stacey, and C. Braun. 2000. Recruitment, dispersal, and demographic rescue in spatially-structured white-tailed ptarmigan populations. The Condor 102:503.

Martin, K., and K. Wiebe. Coping mechanisms of alpine and arctic breeding birds: Extreme weather and limitations to reproductive resilience. Integrative and Comparative Biology 44.

Martin, K., and S. Wilson. 2011. Ptarmigan in North America: Influence of life history and environmental conditions on population persistence. Pages 45 *in* Gyrfalcons and Ptarmigan in a changing world. Volume 1. Idaho.

Martin, K. 2001. Wildlife in Alpine and Sub-alpine habitats. Pages 1-28 *in* Johnson, D.H. and T.A. O'Neil. 2001. Wildlife habitat relationships in Oregon and Washington. Volume 10. Oregon State University Press, Martin, K., and Karen L. Wiebe. 2004. Coping Mechanisms of Alpine and Arctic Breeding Birds: Extreme Weather and Limitations to Reproductive Resilience. Integrative and Comparative Biology 44:177-185. Martin, K., P. B. Stacey, and C. E. Braun. 2000. Recruitment, Dispersal, and Demographic Rescue in Spatially-Structured white-tailed ptarmigan Populations. The Condor 102:503-516. Martin, K., and S. Wilson. 2011. Ptarmigan in North America: Influence of life history and environmental conditions on population persistence. Pages 45-54 *in* R. T. Watson, T. J. Cade, M. Fuller, G. Hunt, and E. Potapov, editors. Gyrfalcons and Ptarmigan in a Changing World, Volume I. The Peregrine Fund, Boise, Idaho, USA.

May, T. A., and C. E. Braun. 1972. Seasonal Foods of Adult white-tailed ptarmigan in Colorado. The Journal of Wildlife Management 36:1180-1186.

May, T. A., and C. E. Braun. 1973. Gizzard Stones from Adult white-tailed ptarmigan (*Lagopus leucurus*) in Colorado. Arctic and Alpine Research 5:49-57. May, T. A. 1975. Physiological ecology of white-tailed ptarmigan in Colorado. University of Colorado. i-311.

McFadden-Hiller. 2017. Distribution of white-tailed ptarmigan in the North Cascades of Washington. 1-13 pp.

McKernan, C., D. J. Cooper, and E. W. Schweiger. 2018. Glacial loss and its effect on riparian vegetation of alpine streams. Freshwater Biology 63:518-529.

Montgomerie, R. 2001. Dirty ptarmigan: behavioral modification of conspicuous male plumage. Behavioral Ecology 12:429-438.

Moss, R. 1973. The digestion and intake of winter foods by wild ptarmigan in Alaska. The Condor 75:293-300.

Mote, P. W., Alan F. Hamlet, Martyn P. Clark, and Dennis P. Lettenmaier. 2005. Declining mountain snowpack in Western North America. Bulletin of the American Meteorological Society 86:39-49.

NatureServe. 2011 *Lagopus leucura*, white-tailed ptarmigan. <www.natureserve.org/explorer/servlet/NatureServe?sourceTemplate=tabular_report.wmt&loadTempl...>. Accessed March 9, 2019.

NPS. 1996. North Country National Scenic Trail Handbook for Trail Design and Construction and Maintenance. U.S. Department of the Interior. <https://www.nps.gov/noco/learn/management/upload/NCT_CH4.pdf.>. 33.

NPS (National Park Service). 2020a. Mount Rainier National Park website. https://www.nps.gov/mora/index.htm Accessed on January 9, 2020..

NPS (National Park Service). 2020b. North Cascades National Park website. https://www.nps.gov/noca/index.htm. Accessed on January 9, 2020.

Oyler-McCance, S. J., C. A. Stricker, J. St. John, C. E. Braun, G. T. Wann, M. S. O'Donnell, and C. L. Aldridge. 2011. Effects of Climate Change on Nutrition and Genetics of white-tailed ptarmigan. Pages 283-294 *in* Ecology, Conservation, and Management of Grouse: Studies in Avian Biology (no. 39). Volume 39. University of California Press, Berkeley. <http://www.degruyter.com/doi/10.1525/9780520950573-023>.

Pacific Northwest Climate Impacts Research Consortium, (CIRC). 2019 Northwest Climate Toolbox. <https://climatetoolbox.org>. Accessed 2019-2020.

Padgett, R. J., Fish and Game Warden, California Department of Fish and Game, Coleville, California. Letter to Glenn Frederick April 11, 1989.

Patil, S. D., S. D. Patil, Y. Gu, F. S. A. Dias, M. Stieglitz, and G. Turk. 2017. Predicting the spectral information of future land cover using machine learning. International Journal of Remote Sensing 38:5592-5607. <http://www.tandfonline.com/doi/abs/10.1080/01431161.2017.1343512>.

Peterson, D. W., B. K. Kerns, and E. K. Dodson. 2014. Climate change effects on vegetation in the Pacific Northwest. <http://purl.fdlp.gov/GPO/gpo75326>.

Ransom, J. 2019. J. Ransom, Wildlife Biologist, North Cascades National Park Service Complex, Sedro-Woolley, WA. Telephone conversation with T. Frederick June 6, 2019.

Raymond, C. L., D. W. Peterson, and R. M. Rochefort. 2014. Climate change vulnerability and adaptation in the North Cascades region, Washington. <http://purl.fdlp.gov/GPO/gpo77949>. 291 pp.

Rehfeldt, G. E., N. L. Crookston, M. Warwell, and J. Evans. 2006. Empirical analyses of plant-climate relationships for the western United States. Int J Plant Sci 167:1123-1150. International Journal of Plant Sciences 167:1123-1150.

Rehfeldt, G. E., N. L. Crookston, C. Sáenz-Romero, and E. M. Campbell. 2012. North American vegetation model for land-use planning in a changing climate: a solution to large classification problems. Ecological Applications 22:119-141.

Riedell, J., and M. Larrabee. 2012. National Park Service: U.S. Department of the Interior. Choice Reviews Online 49.1-38 pp.

Riedell, J., 2019. E-mail correspondence from J. Riedell, Geologist, North Cascades National Park, Sedro-Woolley, WA. September 18 and October 20, 2019.

Revermann, R., H. Schmid, N. Zbinden, R. Spaar, and B. Schröder. 2012. Habitat at the mountain tops: how long can Rock Ptarmigan (*Lagopus muta helvetica*) survive rapid climate change in the Swiss Alps? A multi-scale approach. Journal of Ornithology 153:891-905.

Rice, C. 2012. Status of mountain goats in Washington. Biennial Symposium of the Northern Wild Sheep and Goat Council 18:64-70.

Rixen, C., M. Freppaz, V. Stoeckli, C. Huovinen, K. Huovinen, and S. Wipf. 2008. Altered Snow Density and Chemistry Change Soil Nitrogen Mineralization and Plant Growth. Arctic, Antarctic, and Alpine Research 40:568-575. Robbins, C. T. 1983. Protein requirements for maintenance. Pages ix-165 *in* T. J. Cunha, editor. Wildlife feeding and nutrition. Academic Press, Inc., New York, New York, USA.

Roop, H. A., G. S. Mauger, H. Morgan, A. K. Snover, and M. Krosby. 2019. “Shifting Snowlines and Shorelines: The Intergovernmental Panel on Climate Change’s Special Report on the Ocean and Cryosphere and Implications for Washington State.” Briefing paper prepared by the Climate Impacts Group, University of Washington, Seattle. Population and development review 45:936-937

Sandercock, B. K., K. Martin, and S. J. Hannon. 2005a. Life history strategies in extreme environments: comparative demography of arctic and alpine ptarmigan. Ecology 86:2176-2186.

------ 2005b. Demographic consequences of age-structure in extreme environments: population models for arctic and alpine ptarmigan. Oecologia 146:13-24.

Schmidt, R. K. 1988. Behavior of white-tailed ptarmigan during the breeding season. Pages 270-299 *in* A. T. Bergerud, and M. Gratson, editors. Adaptive strategies and population ecology of northern grouse.

Schroeder, M. 2005. White-tailed ptarmigan *Lagopus leucurus*. Pages 68-69 *in* T. R. Wahl, B. Tweit, and S. G. Mlodinow, editors. Birds of Washington: status and distribution. 1st. edition. Oregon State University Press, Corvallis, OR.

Schroeder, M. 2019. Comments in meeting notes from Mount Rainier white-tailed ptarmigan species status assessment meeting held September 10, 2019.

Scott, C. 2014a. 1980 Mount St. Helens Volcano Eruption (Washington State). Volume 2. 525-529.

Sheehan, T., D. Bachelet, and K. Ferschweiler. 2015. Projected major fire and vegetation changes in the Pacific Northwest of the conterminous United States under selected CMIP5 climate futures. Ecological Modelling 317:16-29.

Shipley, A., J. Cruz, and B. Zuckerberg. 2019/10/02. Deep Snow Creates Microrefugia That Influence Habitat Selection and Behavioral Plasticity in a Winter-Adapted Bird. American Fisheries Society and The Wildlife Society 2019 Joint Annual Conference. Reno, Nevada: 30 September – 3 October 2019. <https://afs.confex.com/afs/2019/meetingapp.cgi/Paper/35059>. Accessed Jun 4, 2020.

Siegel, R. B., P. Pyle, J. H. Thorne, A. J. Holguin, C. A. Howell, S. Stock, and M. W. Tingley. 2014. Vulnerability of birds to climate change in California's Sierra Nevada. Avian Conservation and Ecology 9. Available at <https://www.openaire.eu/search/publication?articleId=doajarticles::06c4874a997c57207d5917270579b2ec>.

Sitts, D. J., A. G. Fountain, and M. J. Hoffman. 2010. Twentieth Century Glacier Change on Mount Adams, Washington, USA. Northwest Science 84:378-385.

Skagen, S. 1980. Ecology and breeding behavior of white-tailed ptarmigan on Sourdough Ridge, North Cascades National Park, Washington. 22 pp.

Smith, D. R., N. L. Allan, C. P. McGowan, J. A. Szymanski, S. R. Oetker, and H. M. Bell. 2018a. Development of a Species Status Assessment Process for Decisions under the U.S. Endangered Species Act. Journal of Fish and Wildlife Management 9:302-320. <https://meridian.allenpress.com/jfwm/article/9/1/302/210492/Development-of-a-Species-Status-Assessment-Process>. Accessed Jun 22, 2020.

Snover, A. K., G. S. Mauger, L. C. Whitely Binder, M. Krosby, and I. Tohver. 2013. Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers. Washington State Department Of Ecology Climate Impacts Group. Accessed 2/6/2020.1-130 pp.

Spear, S. L., C. L. Aldridge, G. T. Wann, and C. E. Braun. 2020. Fine-scale habitat selection by breeding white-tailed ptarmigan in Colorado. The Journal of Wildlife Management 84:172-184.

Spear, S. L. 2017. Factors influencing breeding avifauna abundance and habitat selection in the alpine ecosystem of Colorado. Colorado State University. 164 pp.

State of Washington. 2020. RCW 77.15.400 Unlawful hunting of wild birds—Violation of a rule requiring nontoxic shot—Penalty. RCW 77.15.400

Stinson, D. 2019. Comments in meeting notes from Mount Rainier white-tailed ptarmigan species status assessment meeting held September 10, 2019.

Storch, I. 2007. Grouse, Status survey and conservation Action Plan 2006-2010. Gland, Switzerland: IUCN (International Union for Conservation of Nature and Natural Resources) and Fordingbridge, UK: World Pheasant Association.

Street, P. 2019. Multi-Scale Population Assessment of White-Tailed Ptarmigan. American Fisheries Society and The Wildlife Society 2019 Joint Annual Conference. Reno, Nevada: 30 September – 3 October 2019. <https://afs.confex.com/afs/2019/meetingapp.cgi/Paper/35059>. Accessed Jun 4, 2020.

Stueve, K. M., Dawna L. Cerney, Regina M. Rochefort, and Laurie L. Kurth. 2009. Post-Fire Tree Establishment Patterns at the Alpine Treeline Ecotone: Mount Rainier National Park, Washington, USA. Journal of Vegetation Science 20:107-120.

Taylor, W. 1920. A new ptarmigan from Mount Rainier. The Condor 22:146-152.

The Nature Conservancy. 2010. Conservation Action Planning Workbook.6b Accessed Jan 2019.

US Geological Survey. 2014. USGS Volcano Hazards Program: Mount Rainier. <https://volcanoes.usgs.gov/volcanoes/mount_rainier/mount_rainier_geo_hist_76.html>. Accessed January 16, 2020.

--------2015. USGS Volcano Hazards Program: Glacier Peak. <https://volcanoes.usgs.gov/volcanoes/glacier_peak>. Accessed January 16, 2020.

--------2016. Future Eruptions and Mount Rainier. <https://www.usgs.gov/volcanoes/mount-rainier/future-eruptions-mount-rainier>. Accessed January 16, 2020.

--------2017a. USGS Volcano Hazards Program: Mount Baker. <https://volcanoes.usgs.gov/volcanoes/baker/>. Accessed January 16, 2020

--------2017b. Mount St. Helens Volcanic Eruption. <https://volcanoes.usgs.gov/volcanoes/st_helens/>. Accessed January 16, 2020.

--------2018. USGS Volcano Hazards Program Mt. Adams. <https://volcanoes.usgs.gov/volcanoes/adams/>. Accessed January 16, 2020

USFS. 2020a Interactive Visitor Map. Accessed 2020 June 18,.

--------2020b Okanogan-Wenatchee National Forest. <https://www.fs.usda.gov/recarea/okawen/recarea/?recid=79432>.

USFS (U.S. Forest Service). 2020. Alpine Lakes Wilderness: Okanogan-Wenatchee website. Accessed on January 9, 2020 https://www.fs.usda.gov/recarea/okawen/recreation/hiking/recarea/?recid=79432&actid=51.

USFWS (U.S. Fish and Wildlife Service). 2016. USFWS Species Status Assessment Framework: an integrated analytical framework for conservation. Version 3.4.

Wang, G., T. Hobbs, K. Giesen, H. Galbraith, D. Ojima, and C. Braun. 2002. Relationships between climate and population dynamics of white-tailed ptarmigan *Lagopus leucurus* in Rocky Mountain National Park, Colorado, USA. Climate Research 23:81.

Wann, G. 2017. Reproductive ecology and population viability of Alpine-endemic Ptarmigan populations in Colorado. Graduate Degree, Colorado State University. Fort Collins, Colorado.

Wann, G. 2019. University of Georgia. Peer review of Draft Mount Rainier White-tailed Ptarmigan Species Status Assessment. December 31, 2019.

Wann, G., C. Aldridge, and C. Braun. 2014. Estimates of annual survival, growth, and recruitment of a white-tailed ptarmigan population in Colorado over 43 years. Population Ecology 56:555.

Wann, G. T., C. L. Aldridge, and C. E. Braun. 2016. Effects of seasonal weather on breeding phenology and reproductive success of alpine ptarmigan in Colorado. PLoS ONE 11:1-16. .

Wann, G. T., C. L. Aldridge, A. E. Seglund, S. J. Oyler-McCance, B. C. Kondratieff, and C. E. Braun. 2019. Mismatches between breeding phenology and resource abundance of resident alpine ptarmigan negatively affect chick survival. Ecology and Evolution 9:7200-7212.

Wann, G., C. Aldridge, and C. Braun. 2014. Estimates of annual survival, growth, and recruitment of a white-tailed ptarmigan population in Colorado over 43 years. Population Ecology 56:555-567. Washington Department of Fish and Wildlife. 2015. Washington's State Wildlife Action Plan 2015 Update. Washington State Parks Recreation Commision. 2017. Winter Recreation Strategic Plan
2018-2028. 21 pp.

Webb, D. R. 1987. Thermal Tolerance of Avian Embryos: A Review. The Condor 89:874-898.

Weeden, R. B. 1967. Seasonal and geographic variation in the foods of adult white-tailed ptarmigan. The Condor 69:303-309.

Weeden, R. B. 1959. The ecology and distribution of ptarmigan in western North America. University of British Columbia. White, E., J. M. Bowker, A. E. Askew, L. L. Langner, J. R. Arnold, and D. B. K. English. 2016. Federal outdoor recreation trends: effects on economic opportunities. Gen. Tech. Rep. PNW-GTR-945. U.S. Department Of Agriculture, Forest Service, Pacific Northwest Station. 945.

White, Ken. 2020. Ken White, Skeena Region Entomologist, Smithers British Columbia. Email to Lorraine Maclouchlan, Stephen Burr, and Karen Ripley RE: willow stem boring beetle? February 20, 2020.

Wiebe, K., and K. Martin. 1997. Effects of predation, body condition and temperature on incubation rhythms of white-tailed ptarmigan, *Lagopus leucurus*. Wildlife Biology 3:219-227.

-------- 1998a. Age-specific patters of reproduction in white-tailed and willow ptarmigan *Lagopus leucurus* and *L. lagopus*. Ibis 140:14.

-------- 1998b. Costs and benefits of nest cover for ptarmigan: changes within and between years. Animal Behaviour 56:1137-1144.

-------- 2000. The use of incubation behavior to adjust avian reproductive costs after laying. Behavioral Ecology and Sociobiology 48:463-470.

Wilson, S., and K. Martin. 2008. Breeding habitat selection of sympatric white-tailed, rock and willow ptarmigan in the southern Yukon Territory, Canada. Journal of Ornithology 149:629-637.

-------- 2010. Variable reproductive effort for two ptarmigan species in response to spring weather in a northern alpine ecosystem. Journal of Avian Biology 41:319-326.

-------- 2011. Life-history and demographic variation in an alpine specialist at the latitudinal extremes of the range. Population Ecology 53:459-471.

-------- 2012. Influence of life history strategies on sensitivity, population growth and response to climate for sympatric alpine birds. BMC Ecology 12:1-10.

Zwinger, A., and B. Willard. 1972. Land Above the Trees. Harper & Row. New York, New York.

Appendices

Appendix A. Comparison of Climate in Cascades, Sierra Nevada, and Southern Rockies

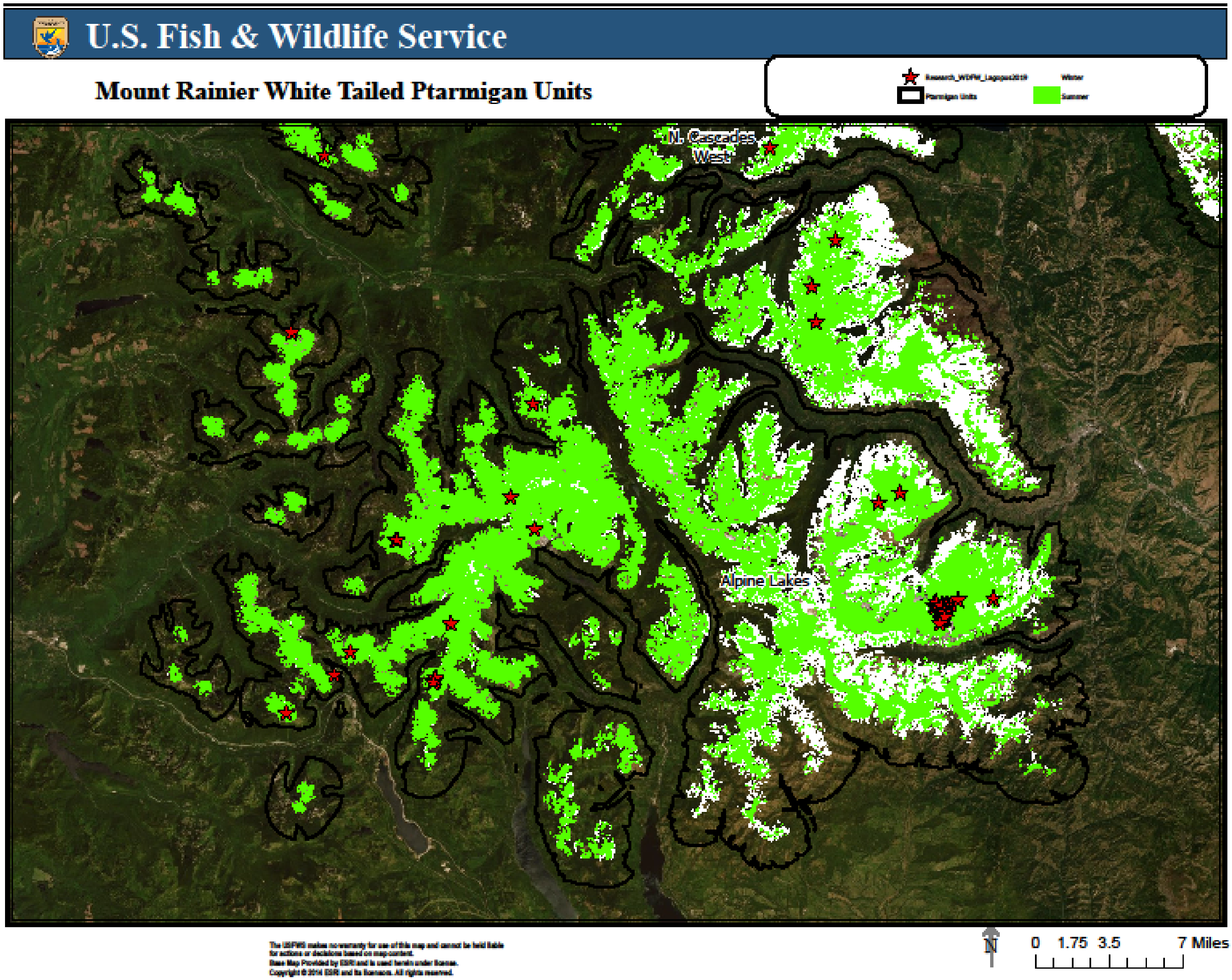
30-yr Normals (Climate Toolbox - 1971-2000 Historical Simulation)
The mean/SD/min/max values in the tables are average values across the areas shown on the map to the right of the table (WTP range maps)

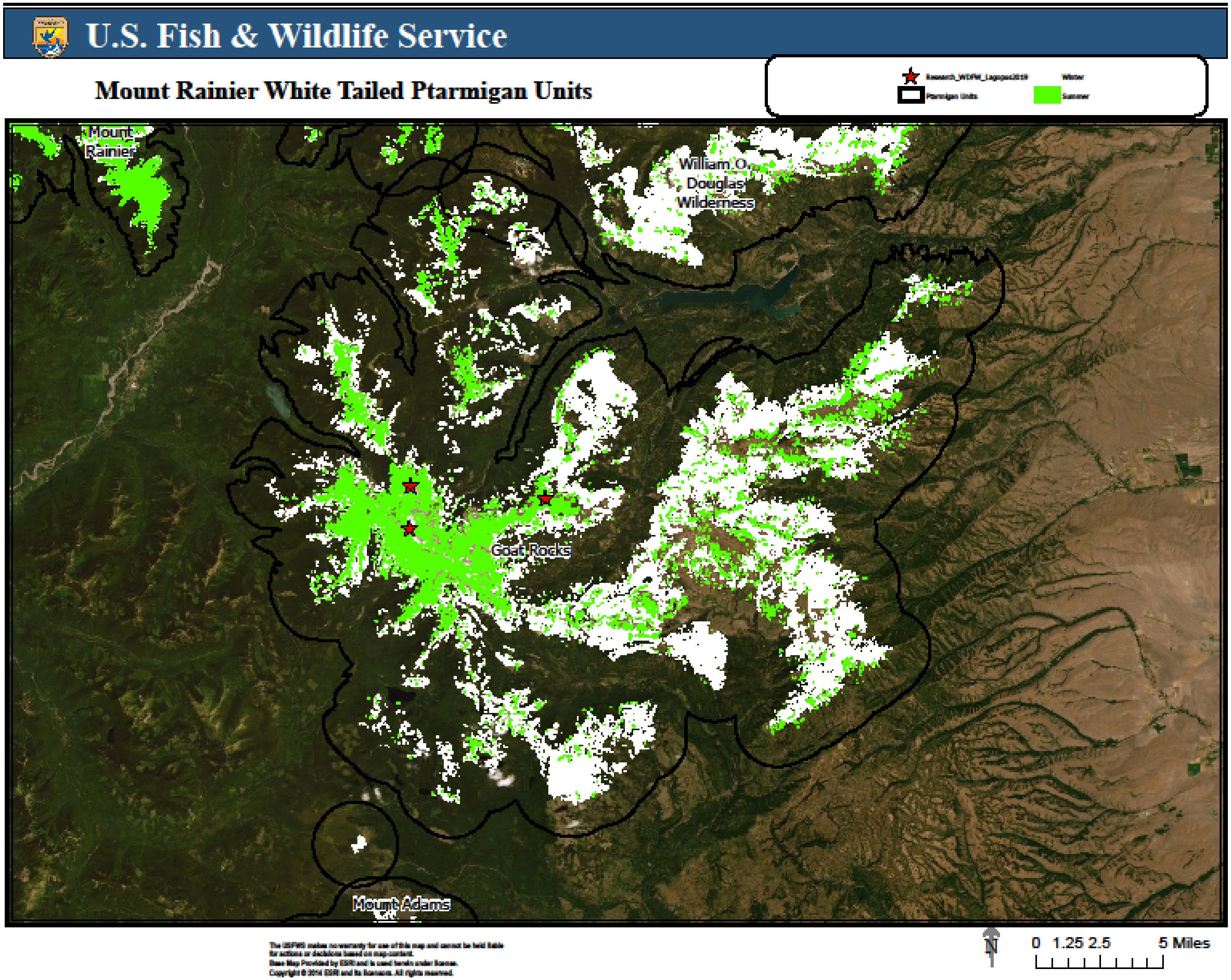
		30-year Normals (1971-2000)											
		Cascades (WA)				**Sierra Nevada (CA)**				**Rocky Mountains (CO)**			
		mean	SD	min	max	mean	SD	min	max	mean	SD	min	max
TMEAN (deg F)	Winter (DJF)	24.21	2.78	9.38	32.26	24.03	2.59	17.82	31.35	15.79	2.02	11.12	21.96
	Spring (MAM)	35.25	2.76	14.24	43.70	31.98	2.98	25.21	39.99	28.88	2.01	23.25	35.45
	Summer (JJA)	52.51	2.99	30.10	62.67	50.96	3.08	43.79	58.73	48.28	2.11	42.66	55.78
	Fall (SON)	38.54	2.60	21.19	45.06	38.50	2.85	31.36	45.92	32.32	1.95	27.21	39.34
TMIN (deg F)	Winter	18.90	3.00	3.18	27.53	13.67	2.36	8.52	22.33	4.48	1.87	-1.18	10.69
	Spring	26.44	2.71	5.79	33.70	20.70	2.66	14.88	29.01	16.36	2.03	11.11	22.92
	Summer	41.77	2.63	20.55	50.00	39.94	2.50	34.70	47.17	35.39	2.23	29.19	42.15
	Fall	30.99	2.59	13.73	38.12	28.23	2.29	22.94	35.79	21.00	1.89	15.77	26.94
TMAX (deg F)	Winter	30.33	2.60	15.59	37.76	34.39	3.11	26.47	42.66	27.11	2.63	21.45	34.15
	Spring	44.07	2.97	22.69	53.93	43.25	3.50	35.28	51.92	41.40	2.25	34.18	48.00
	Summer	63.25	3.54	39.65	75.48	61.97	4.14	52.39	72.76	61.18	2.30	54.54	69.41
	Fall	46.09	2.72	28.65	53.89	48.77	3.73	39.19	57.74	43,64	2.28	37.46	51.74
PRECIP (in)	Winter	26.77	12.83	5.17	80.25	21.06	6.47	6.50	34.40	9.71	3.25	2.99	20.96
	Spring	14.52	7.12	3.58	44.70	10.56	3.05	3.43	17.59	10.71	2.37	4.33	18.64
	Summer	5.80	2.04	2.04	15.29	1.47	0.51	0.56	3.33	7.06	1.19	4.56	12.43
	Fall	19.43	10.39	3.71	62.40	6.54	2.33	2.89	13.36	8.77	2.26	4.17	15.77
# days > 90F	Annual	0	0	0	0	0	0	0	0	0	0	0	0

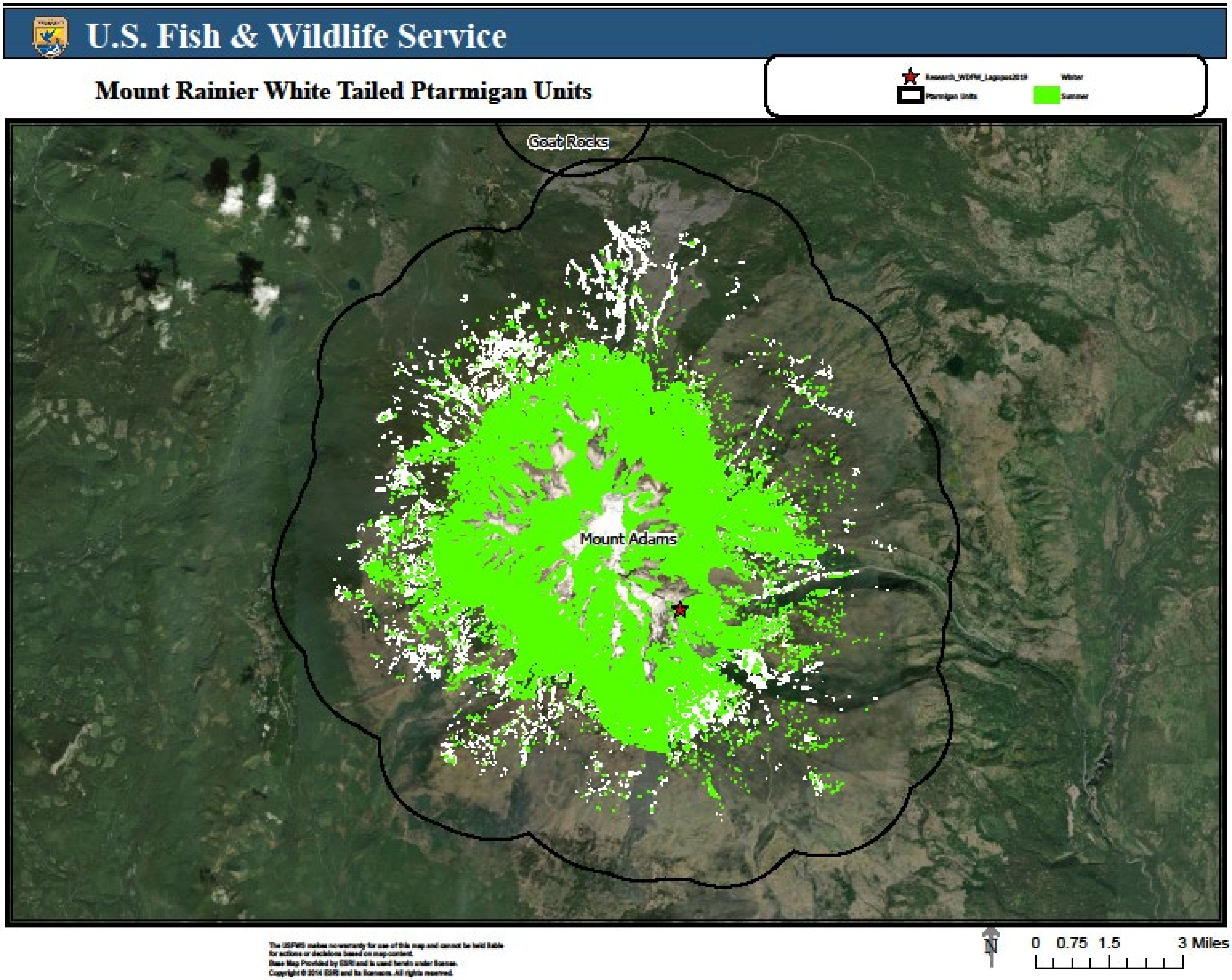
Appendix B. Frequency of 917 white-tailed ptarmigan observations within USFWS database as of March, 2020 within each vegetation type in Washington as mapped by NPS and Landfire.

Vegetation Type	Percent of Observations
North Pacific Alpine and Subalpine Bedrock and Scree	46.0%
North Pacific Dry and Mesic Alpine Dwarf-Shrubland	19.0%
M63 Sparse Alpine Vegetation	12.2%
North Pacific Maritime Mesic Subalpine Parkland	4.7%
M74A Alpine Heather Parkland	4.5%
Northern Rocky Mountain Subalpine Woodland and Parkland	4.3%
North Pacific Alpine and Subalpine Dry Grassland	3.4%
M74S Subalpine Mountain Heather Dwarf Shrubland	1.5%
M64E Alpine Buckwheat t Davis Knotweed Pumice Fellfield Vegetation	1.0%
North Pacific Dry and Mesic Alpine Fell-field or Meadow	1.0%
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	1.0%
M15 Krummholz	0.3%
M86 Showy Sedge o Sitka Valerian Meadow	0.3%
North Pacific Montane Riparian Woodland	0.2%
M17M Mount Rainier Subalpine Fir Whitebark Pine Woodland	0.1%
M52 Mount Rainier Subalpine Forb Graminoid Meadow	0.1%
M64L Spreading Phlox Prairie Lupine Pumice Fellfield Vegetation	0.1%
North Pacific Montane Riparian Shrubland	0.1%
Rocky Mountain Subalpine-Montane Riparian Woodland	0.1%
Temperate Pacific Subalpine-Montane Wet Meadow	0.1%
Total	100.0%

Appendix C. Maps of each white-tailed ptarmigan population unit used in the SSA Analysis.

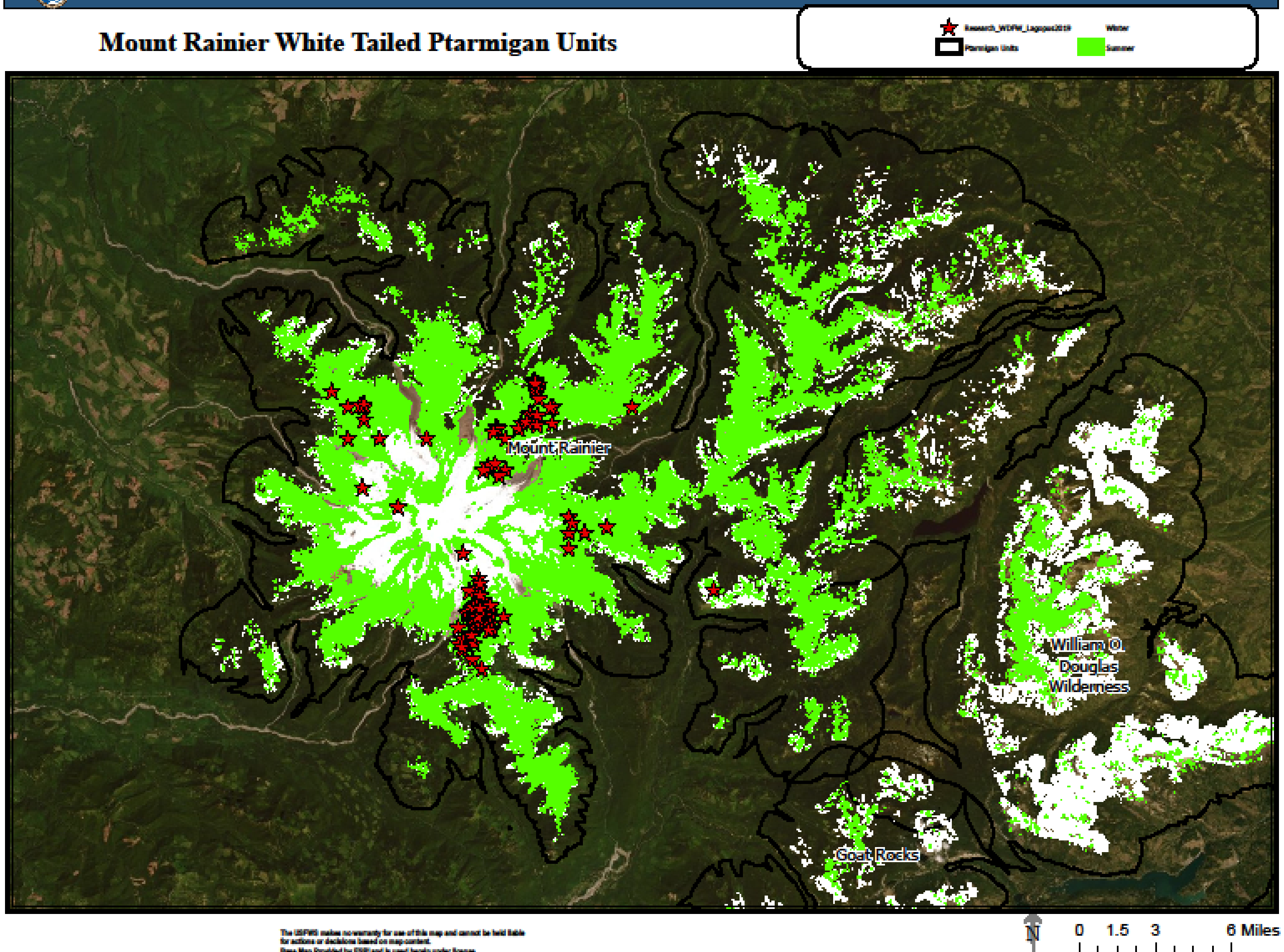


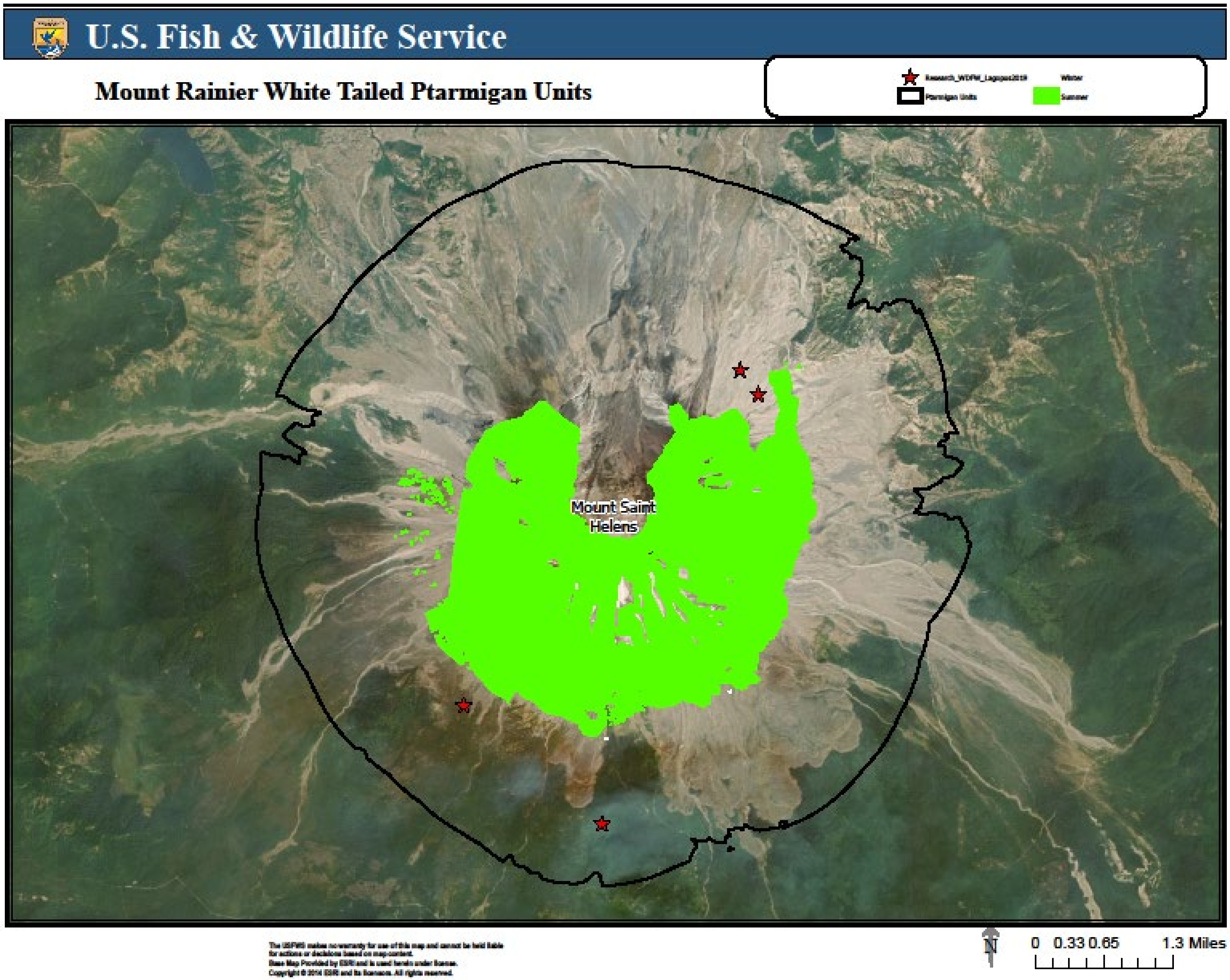

U.S. Fish & Wildlife Service
Mount Rainier White Tailed Ptarmigan Units
Winter
Summer
Mount Rainier
William O. Douglas Wilderness
Goat Rocks
Mount Adams
N
0 1.25 2.5 5 Miles


U.S. Fish & Wildlife Service
Mount Rainier White Tailed Ptarmigan Units
Winter
Summer
Goat Rocks
Mount Adams
N
0 0.75 1.5 3 Miles
The USFWS makes no warranty for use of this map and cannot be held liable for actions or decisions based on map content.
Base Map Provided by ESRI and is used herein under license.
Copyright © 2014 ESRI and its licensors. All rights reserved.

U.S. Fish & Wildlife Service

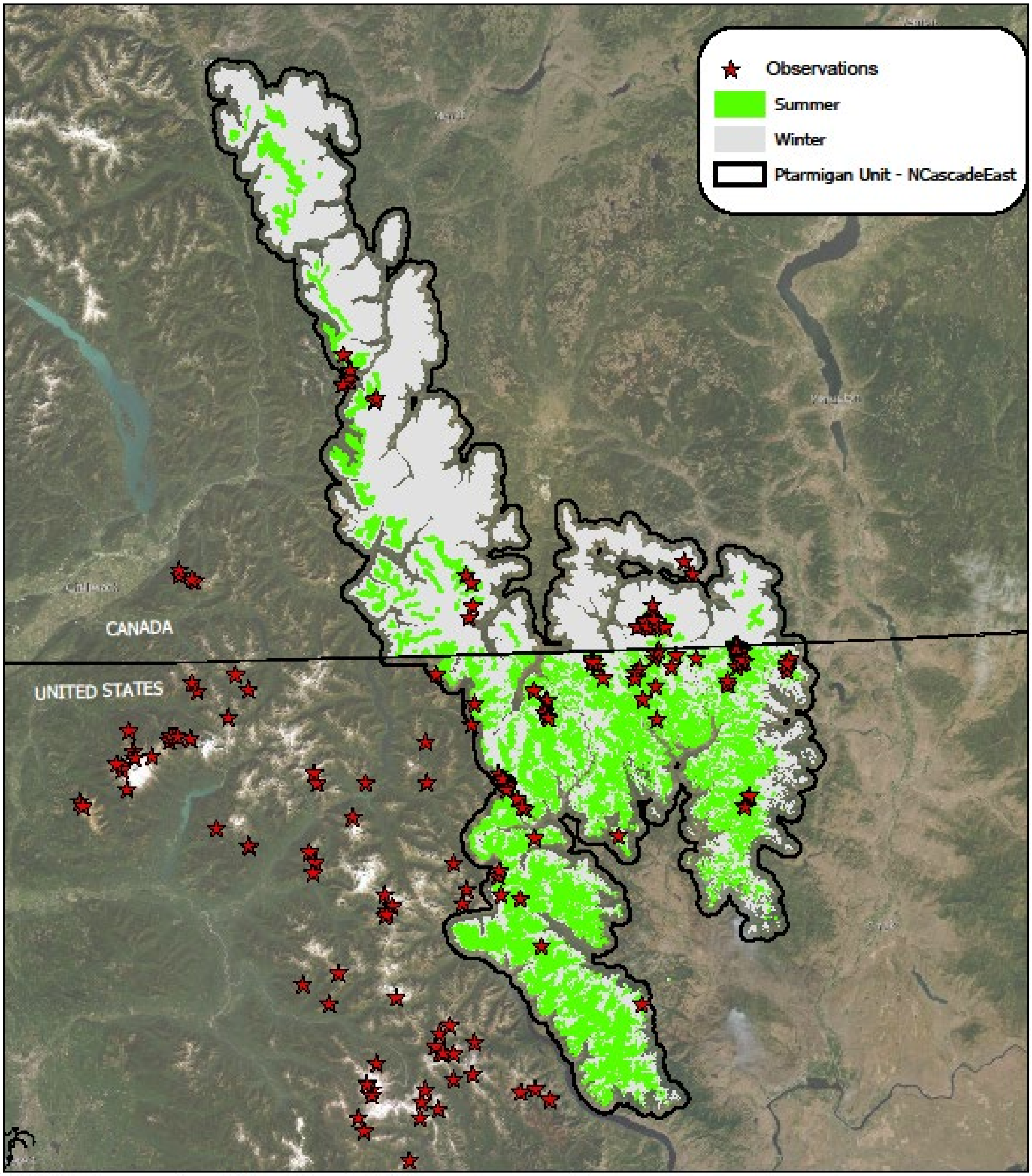
Mount Rainier White Tailed Ptarmigan Units




U.S. Fish & Wildlife Service
Mount Rainier White Tailed Ptarmigan Units
Winter
Ptarmigan Units
Summer
Mount Saint Helens
N
0 0.33 0.65 1.3 Miles

U.S. Fish and Wildlife Service

Mount Rainier White Tailed Ptarmigan Units



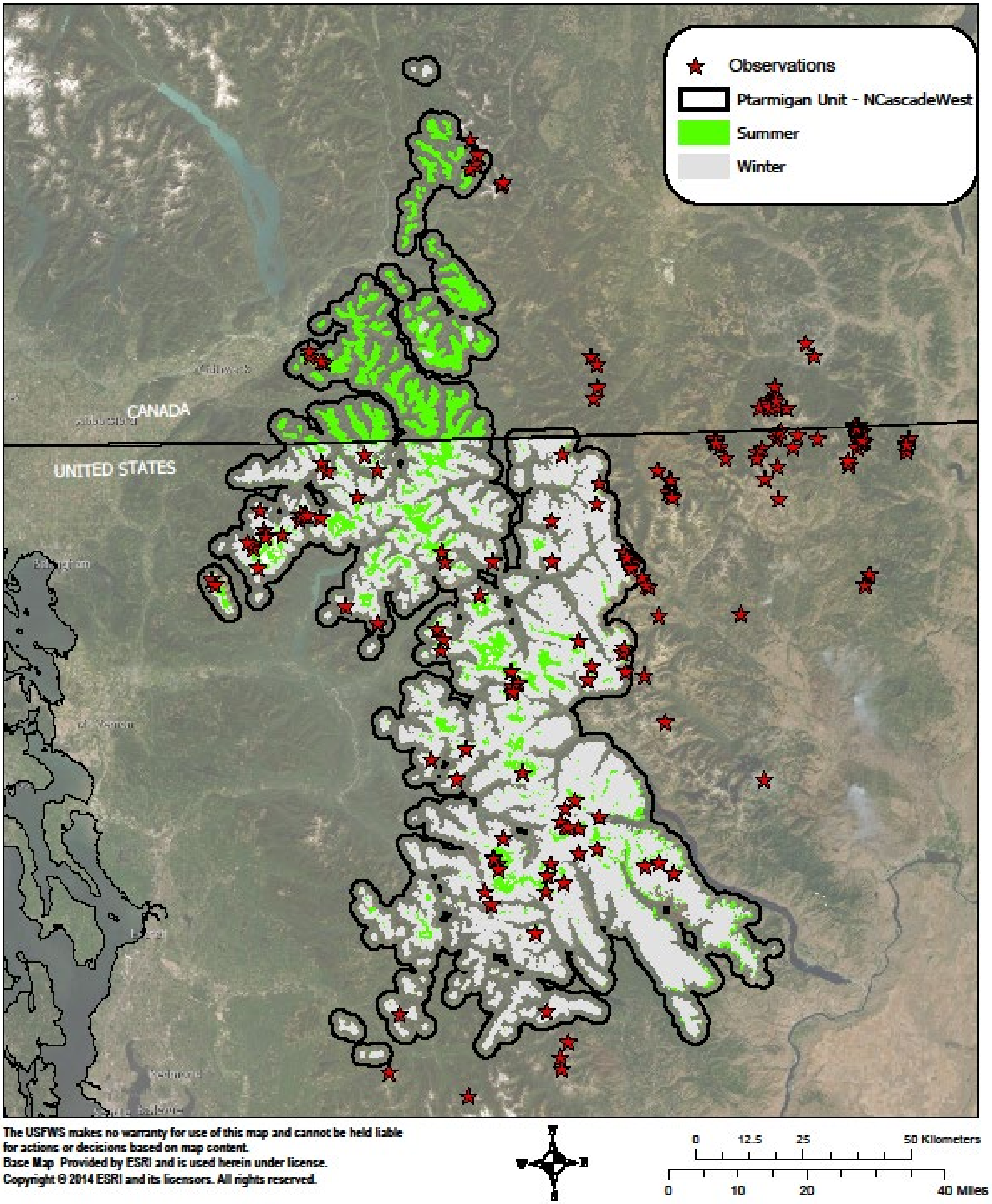
The USFWS makes no warranty for use of this map and cannot be held liable for actions or decisions based on map content.
Base Map Provided by ESRI and is used herein under license.

0 12.5 25 50 Kilometers

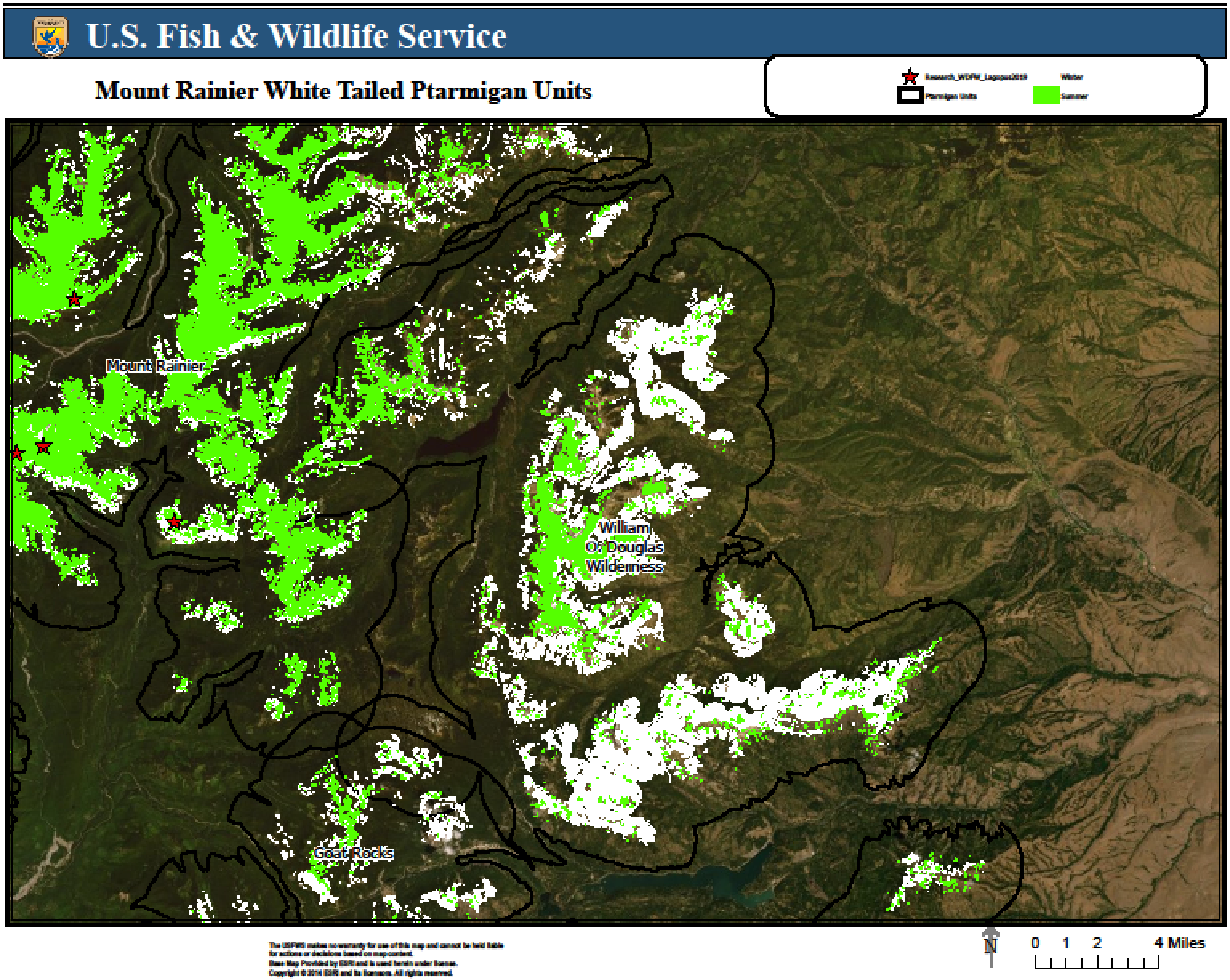
0 10 20 40 Miles

U.S. Fish and Wildlife Service

Mount Rainier White Tailed Ptarmigan Units



The USFWS makes no warranty for use of this map and cannot be held liable for actions or decisions based on map content.
Base Map Provided by ESRI and is used herein under license.


U.S. Fish & Wildlife Service
Mount Rainier White Tailed Ptarmigan Units
Ptarmigan Units
Winter
Summer
Mount Rainier
William O. Douglas Wilderness
Goat Rocks
N
0 1 2 4 Miles
The USFWS makes no warranty for use of this map and cannot be held liable for actions or decisions based on map content.
Base Map Provided by ESRI and is used herein under license.
Copyright © 2014 ESRI and its licensors. All rights reserved.

Appendix D. Current and projected acres of breeding and post-breeding habitat for Mount Rainier white-tailed ptarmigan.

Population Unit	Habitat Type	Current (ac)	Hadley A2 2090 (ac)	Consensus A2 2090 (ac)	CGCMS A2 2090 (ac)
Alpine Lakes	Western Alpine Tundra	27,640.70			
Mount Rainier	Western Alpine Tundra	38,680.61	104.27	755.09	1,479.89
N. Cascades East	Western Alpine Tundra	51,998.38			
N. Cascades West	Western Alpine Tundra	160,985.31		415.44	278.95
Goat Rocks	Western Alpine Tundra	10,123.29			
William O. Douglas	Western Alpine Tundra	11,064.08			
Total		300,492.37	104.27	1,170.53	1,758.83