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The Effects of Climate Change on Six Bird Species Across an Elevational Gradient

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INTRODUCTION

Climate change has rapidly become one of the most pervasive threats to the diversity and integrity of the global ecosystem. In recent years, the anthropogenic acceleration of climate change has led to the amplification of concerning climatic patterns, including a significant increase in yearly global temperature, the intensification of severe weather, a rising frequency of drought and widespread dryness, and the degradation of innumerable habitats (Trenberth 2011, Lindsey and Dahlman 2020). The effects of these impacts often lead to radical changes in species distribution at every level, from individual populations to entire ecosystems (Karl et al. 2009).

Such trends are especially critical in mountainous regions. Systems situated at higher altitudes exhibit a phenomenon known as "elevation-dependent warming," wherein alpine zones experience warming trends that are more pronounced than the global land average (Rangwala and Miller 2012). This sensitivity to rising temperatures is thought to be attributed to an increase in melting snow and ice, which then reduces surface albedo, and in turn augments additional heating (Pepin and Lundquist 2008). A feedback loop that exacerbates hotter, drier conditions – such as the aforementioned – is dangerous, particularly in high-elevation habitats. Mountains are widely considered to be the "water towers" of the world, as they provide a tremendous majority of the world's surface water via downstream snowmelt and glacial runoff (Messerli et al. 2004). Alterations to these vastly important hydrological cycles are expected to have considerable negative impact on the stability of the biota and ecosystems they support.

In addition to many of these universal climate impacts, alpine communities are also faced with a unique problem in response to increasing temperatures. As conditions grow warmer and more arid, many organisms will be forced to shift their range to higher-elevation climate refugia or face population- or species-level extinction (Graherr et al. 2010). This "uphill retreat" event is already taking place, and a number of studies have documented the redistribution of species towards higher altitudes in plants, insects, and amphibians (Thomas et al. 2006, Frei et al. 2010). Climate refugia serve as a safe haven for low elevation species. However, therein lies the dilemma for alpine communities: there is no "uphill" for those already living at the top. Instead, these species are subjected to their own unprecedented array of problems, and are threatened threefold. First, as previously mentioned, high-elevation species are more likely to experience intensified trends in temperature due to the susceptibility of mountain ecosystems to elevation-dependent warming (Rangwala and Miller 2012). Secondly, alpine communities are more likely to face sharp population declines as a result of their altitudinal position, which leaves no room to retreat down the mountain in search of potential climate refugia (Seastedt and Oldfather 2021). Finally, many high-elevation specialists will be outcompeted by species moving uphill, leaving ecosystem assemblages permanently altered (Albrich et al. 2021). For these reasons, it is critical that the vulnerability and resilience of alpine communities and their resident species be assessed in order to inform effective management in response to climate change.

In North America, this is the conundrum faced by many high-elevation specialists in the Rocky Mountains. This paper focuses on six species of bird – three belonging to the category of habitat generalists, and three belonging to the category of high-elevation habitat specialists that are confronted with the threats described. Birds were selected as the subject of interest due to the availability of data pertaining to their biology and habitat; they are the best-studied group of organisms with regard to climate research, and the efforts of citizen science projects have revealed much about the distributions and life histories of thousands of species, including those in remote mountain locations (Wormworth and Sekercioglu 2011). This paper seeks to utilize this data to assess and compare the vulnerability of bird species to climate change across an elevational gradient in the Rocky Mountains.

METHODS

Six avian species endemic to the Rocky Mountains were selected to assess for their vulnerability to climate change: the black-capped chickadee (*Poecile atricapillus*), the yellow warbler (*Setophaga petechia*), the American robin (*Turdus migratorius*), the American pipit (*Anthus spinoletta*) the gray-crowned rosy-finch (*Leucosticte tephrocotis*), and the white-tailed ptarmigan (*Lagopus leucura*). Of these six species, three were chosen for their status as abundant habitat generalists that generally inhabit a wide range of elevations (black-capped chickadee, yellow warbler, and American robin). The other three species were chosen due to their character as specialists that require extreme, high elevation habitats to breed and reproduce (American pipit, gray-crowned rosy-finch, and white-tailed ptarmigan). The altitudinal distributions of the selected birds creates an approximate elevational gradient (Figure 1), across which the vulnerability of these species can be compared.

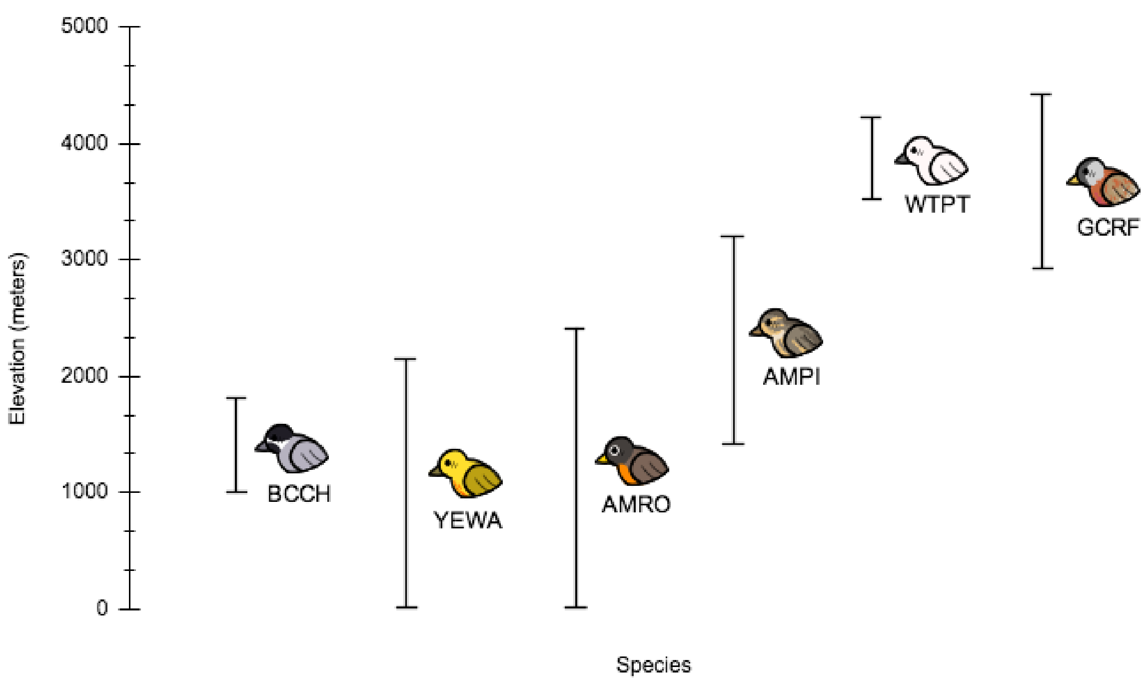

Figure 1. Approximate elevational ranges of breeding habitats of the six species included in this study.

In order to establish the vulnerability of each species, the System for Assessing Vulnerability of Species (SAVS) was used. Developed by the United States Forest Service and the Rocky Mountain Research Station, the SAVS questionnaire is a tool designed to address the capacity of vertebrate species to adapt to climate change (Bagne et al. 2011). It is comprised of 25 questions that encompass specific aspects of habitat, physiology, phenology, and biotic interactions in response to various climate factors. After they have been answered, each question is assigned a point value of +1, 0, or -1. A score of +1 indicates that the species exhibits a vulnerability to climate change in that particular area, while a score of -1 indicates that that species exhibits a resilience to climate change in that particular area. A score of zero indicates that that species is largely unaffected.

A total score for each species can then be calculated. Because the 25 questions are not distributed evenly across the four categories (habitat, physiology, phenology, and biotic interactions), each category is designated its own simple formula for calculating the respective score. They can then be totalled together to determine the overall score; it will fall between the values -20 and +20. For each species, an overall positive score suggests that climate change is likely to threaten that organism, and its impacts will be costly, to some degree. Conversely, an overall negative score suggests that climate change is not likely to threaten the organism, and its impacts may confer benefits, to some degree.

To answer the questions provided on the SAVS questionnaire, a combination of published literature and primary research found on both the Web of Science and Google Scholar databases were utilized. In addition to this, this paper also used the species-specific information compiled on birdsoftheworld.org, which is organized, run by, and updated by the Cornell Lab of Ornithology.

RESULTS

Overall Scores

Overall scores were calculated using all 25 questions provided on the SAVS questionnaire. Possible scores ranged from -20 to +20; actual scores from the assessment ranged from -0.1 to +8.5 (Figure 2). Of the six species, five retained a positive score. This indicates that there is some degree of vulnerability to climate change in a majority of the species.

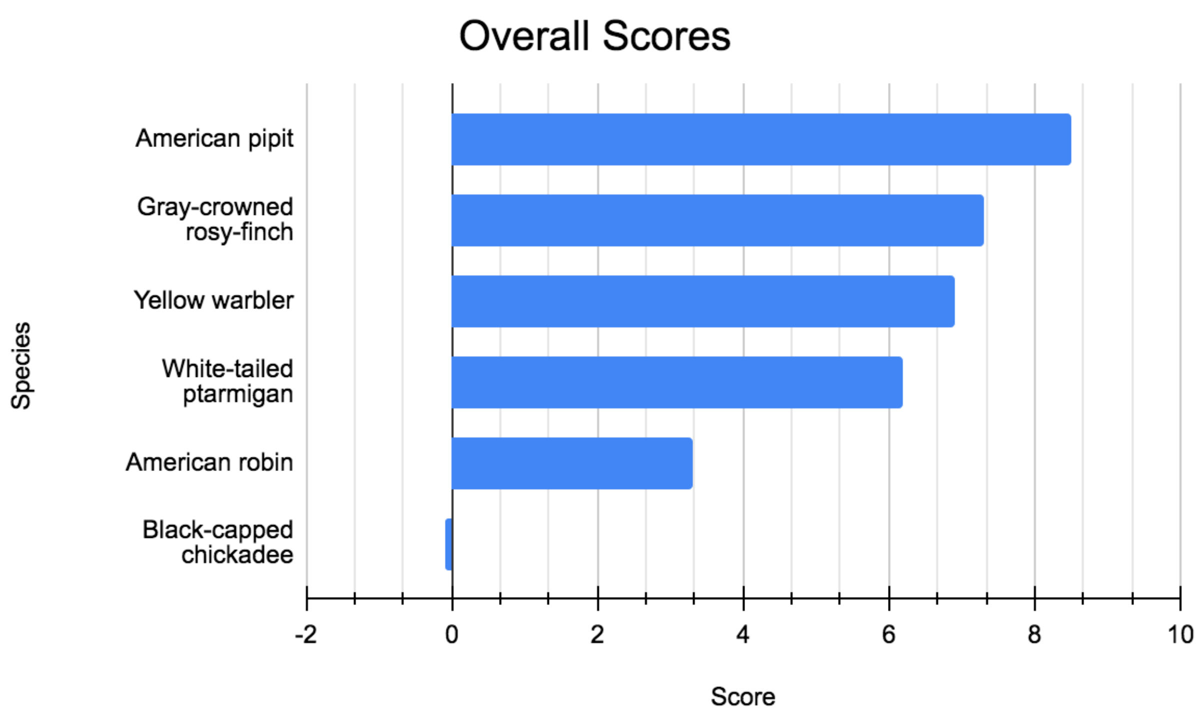

Figure 2. Bar graph depicting the overall scores for each of the six species assessed.

The American pipit was the most highly-scoring species with a score of +8.5, followed closely by the gray-crowned rosy-finch with a score of +7.3. Both species received a positive score ("vulnerable") on 11 of the questions. Conversely, the black-capped chickadee was the lowest-scoring species with an overall score of -0.1. It received a negative score ("resilient") on five of the questions, and a zero score ("neutral") on 14 of the questions.

The average score for the generalists was +3.4, while the average score for the specialists was +7.3. Although all of the specialist species scored highly, the trend in their scoring distributions does not follow the elevational gradient described in Figure 1. Instead, the yellow warbler (a generalist) outscores the white-tailed ptarmigan (a specialist), and the most elevationally-extreme species (the gray-crowned rosy-finch) does not exhibit the most vulnerability according to the model.

Categorical Scores

Categorical scores were calculated for each of the four categories used by the SAVS tool, including habitat, physiology, phenology, and biotic interactions. The possible scores range from -5 to +5. The physiology category had the highest average score (+2.7), followed by phenology (+2.1), then habitat (+0.4), and finally biotic interactions (+0.2). The scores for each category in each species is recorded in Table 1.

Scores in the habitat category ranged from -2.5 to +1.3. Both the gray-crowned rosy-finch and the black-capped chickadee shared the high score of 1.3, while the American robin exhibited a strong resilience in this category at -2.5. The American robin was the only species to receive a negative score in this category.

Scores in the physiology category ranged from -1.2 to +4.2. All three high-elevation specialists (gray-crowned rosy-finch, American pipit, and white-tailed ptarmigan) were threatened in this category, as they shared the exact same high score of 4.2. The black-capped chickadee was the only species to display resilience in this category, with its score of -1.2.

Scores in the phenology category ranged from +0.8 to +3.8. The yellow warbler and the American pipit shared the high score of +3.8. The two nonmigratory species that were assessed (white-tailed ptarmigan and black-capped chickadee) scored a low of +0.8. This is the only category in which all six species were vulnerable in some capacity.

Scores in the biotic interactions category had the smallest variation, and each species scored either -1, 0, or +1. The yellow warbler and gray-crowned rosy-finch received a positive score, while the black-caped chickadee received the only negative score.

Species	Overall Score	Habitat	Physiology	Phenology	Biotic Interactions
American pipit	8.5	0.5	4.2	3.8	0.0
Gray-crowned rosy-finch	7.3	1.3	4.2	0.8	1.0
Yellow warbler	6.9	0.6	1.5	3.8	1.0
White-tailed ptarmigan	6.2	1.2	4.2	0.8	0.0
American robin	3.3	-2.5	3.3	2.5	0.0
Black-capped chickadee	-0.1	1.3	-1.2	0.8	-1.0

Table 1. Overall and categorical vulnerability scores for each of the six species assessed. Overall scores range from -20 to +20, and categorical scores range from -5 to +5.

DISCUSSION

The assessment conducted demonstrated that all six species of birds evince some degree of vulnerability to climate change according to the multiple criteria of the SAVS tool. This is true regardless of whether or not the species was considered a generalist or specialist; even the black-capped chickadee, which received the only "resilient" (negative) score, was ranked as vulnerable for 6 out of the 25 criteria.

On average, the three generalist species (black-capped chickadee, yellow warbler, and American robin) scored lower than the three specialist species (American pipit, white-tailed ptarmigan, and gray-crowned rosy-finch). This difference is most apparent in their average overall scores, wherein the generalists scored +3.4 and the specialists scored +7.3. The specialist species also demonstrated a higher average vulnerability score in all categories, with the exception of phenology. This makes sense, as it indicates that these birds are threatened by a variety of factors due to their unique niche. For example, bird species residing at high altitudes are adapted to withstanding cold weather and often have inadequate physiological thresholds to support acclimatization to warmer conditions, thus exacerbating susceptibility to heat-related mortality (Şekercioğlu et al. 2012). They are also imperiled by the movement of other species upslope. Montane communities will be dramatically reshaped as they are colonized by lowland species – high-elevation birds may see population-level extirpation as they are outcompeted by more adaptable generalist bird species (Freeman et al. 2018). And, even if no direct competitors move uphill, the transformation of invertebrate and plant species assemblages could leave avian specialists without necessary nesting materials, sufficient foraging areas, or suitable food choices (Thomas et al. 2006). These factors, in combination with the inability to retreat uphill, may serve to explain why the high-elevation specialists in this paper maintain a higher average vulnerability score than their generalist counterparts.

All that being said, the vulnerability scores do not exactly match the elevational distributions described in Figure 1. Interestingly, the yellow warbler outscores the white-tailed ptarmigan regardless of its role as a generalist species, and the American pipit retains the highest vulnerability score even though the gray-crowned rosy-finch and the white-tailed ptarmigan live in more extreme altitudes. This trend could be a result of the migratory status of these species;

long-distance migrants in particular are thought to be more susceptible to the effects of a changing climate. Migrants undertake long, arduous journeys that have become more dangerous as weather patterns grow more extreme, and rerouting to safer paths is often thwarted by human land-use change (Barlein 2016). Most notably, these species are threatened by their heightened potential for migrational mistiming as climatic variables between disparate breeding and nonbreeding grounds become erratic (Robinson et al. 2009). Indeed, the migratory species assessed in this paper had an average vulnerability score of +6.5, while the nonmigratory species had a score of +3.1, indicating that migrants may be more at-risk.

However, it is impossible to draw a definitive conclusion about the link between climate vulnerability and migratory status based on the assessment conducted in this paper alone. Of the six species reviewed, four were considered migratory (American pipit, American robin, gray-crowned rosy-finch, and yellow warbler), while two were considered nonmigratory (white-tailed ptarmigan, black-capped chickadee) – these sample sizes are small and unequal, and thus do not provide an accurate comparison between groups. Additionally, the term “migratory” is quite broad under the SAVS criteria, and is applied systematically to all species which have separate breeding and wintering grounds. This means that the yellow warbler, which travells thousands of miles to South America, is placed in the same category as the gray-crowned rosy-finch, which only moves short distances downslope to escape the cold in the winter season.

This is one of many potential shortcomings of the SAVS tool, which may explain some of the inconsistencies in the resulting trends. The criteria in the model itself were scored on a binary scale of -1, 0, or +1, and each question was weighted approximately equally. This is perhaps an oversimplification of the realities of many organisms and their ecosystems; certain factors are likely to exhibit a larger magnitude of influence over species survival than others. For example, the gray-crowned rosy-finch received a “vulnerable” score because it (a) does not participate in caching behaviours, and thus cannot store food in the long-term, and (b) because its primary breeding habitat in cold, alpine locations is likely to be threatened by increasing temperatures, glacial recession, and colonization by competing species. The availability and quality of breeding habitat is more likely to have a profound impact on population demographics than the ability to store food. The argument that these factors would place equal pressure on the survivorship of the gray-crowned rosy-finch is a misrepresentation supported by the SAVS assessment.

Additionally, although the SAVS model addresses a wide assortment of factors that affect the vulnerability of species under climate change, it is likely that more factors do exist or will exist in the future that are not considered. Furthermore, the SAVS tool is designed to evaluate any vertebrate species – not just birds – thus many of the questions were broadly applicable and some overlap between assessments occurred. This may serve to artificially inflate or deflate scores; for example, all six species reviewed in this paper received a score of -1 on question seven of the habitat category, which inquires whether or not the species displays capacity for dispersal. Because each of the analyzed bird species can fly, they were all deemed uniformly resilient under this criteria despite differences in their ability to cover long distances. If the questions asked were more precisely defined, then the questionnaire may produce more accurate scores that are specific to the taxonomic group or individual species being assessed.

Regardless of the imperfections in the implementation of the SAVS model, one of its major strengths is explicitly identifying uncertainty in our understanding of species’ climate responses. This is especially important when considering high-elevation specialists like the gray-crowned rosy-finch, which lives in extreme, isolated habitats that make conducting thorough research difficult. When assessing this species, 6 of the 25 criteria were answered with the caveat of that trait being understudied or altogether unknown. While this certainly may contribute to an underestimation of the gray-crowned rosy-finch's vulnerability score, it also suffices to illuminate which areas of its physiology and breeding biology require further investigation. This knowledge is critical for developing species-specific plans to comprehensively address how climate factors might influence population survival and persistence.

Ultimately, although this paper reflects only a very small-scale review of North American bird species along an elevational gradient, the information compiled in the SAVS questionnaire is still a useful tool to assist in predicting the climate responses of the bird species assessed. The SAVS model takes a holistic approach to assessing the vulnerability of species, and although it has its drawbacks, it still adequately identifies a number of useful criteria – such as important habitat characteristics, phenological mismatches, and significant interactions with other species – that can inform environmental stewardship or conservation initiatives. Overall, the biggest takeaway from this assessment was that each of the six species were threatened by climate change in some way; this further highlights the need for reliable research and effective management plans in order to preserve biodiversity in the face of a changing climate.

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APPENDIX
<u>GENERALISTS</u>
AMERICAN ROBIN (*Turdus migratorius*) – HABITAT

Trait/Quality	Question	Background information & explanation of score	Points
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	The American robin is one of the most abundantly distributed and adaptable species of bird in North America. They chiefly breed in short-grass areas with some foliage, such as shrubs or trees (Vanderhoff et al. 2020). As such, robins take advantage of a number of habitat types, including forested lots, woodlands, and gardens. In unaltered environments, robins prefer to nest by streams and rivers, and breeding populations are observed in higher abundance in riparian zones (Tewksbury et al. 2002). Robins are also more likely to nest in early-successional stage forests; in several study sites across the Pacific Northwest and British Columbia, robins selected burned, logged, or otherwise disturbed plots of land over old-growth late successional plots (Martin 1973). Although riparian zones will certainly decrease due to the effects of climate change, the American robin is an incredible habitat generalist. They are prolific in altered habitats along rivers and streams, as well as in residential towns, urban parks, and farmlands (Vanderhoff et al. 2020). In the American west, the conversion of riparian regions into agricultural or urban development has caused robin populations to increase (Tewksbury et al. 2002). The breeding range of American robins has expanded into what would be hostile environments (eg, northern Canada) in response to human settlement (Staniforth 2002).	**-1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	The American robin is not a long-distance migrant, and instead will move to lower elevations or more southerly regions to overwinter. Because of this, their nonbreeding habitat is largely similar to their breeding habitat, and includes forests, shrub-steppes, agricultural lowlands, and open pastures or lawns (Vanderhoff et al. 2020). There is no evidence to suggest that they fare comparatively better in forested, urban, or exurban areas while they overwinter.	**0**
3. Habitat components : *breeding*	Are specific habitat components required for breeding expected	No specific habitat components were identified; American robins are versatile in their nesting choices and can successfully raise young on the ground, in low thickets, or in high treetops (Vanderhoff et al. 2020).	**0**

	to change?		
4. Habitat components: *nonbreeding*	Are specific habitat components required for survival during non-breeding periods expected to change?	During the nonbreeding season, American robins will alter their diet composition drastically. In the spring and summer, robins feed primarily on small terrestrial invertebrates such as insects and earthworms (Vanderhoff et al. 2020). However, analyses of robin stomach contents indicate that over 90% of their diet during the winter consists of fruits, especially those of the English hawthorn, chokecherry, juniper, and invasive honeysuckle species (Wheelwright 1986, Vanderhoff et al. 2020). Overwintering habitats must contain an adequate number of fruiting plant species in order to support this diet. Although drier conditions will likely reduce the number of native plant species, this is unlikely to cause widespread harm to American robin populations; robins demonstrate a propensity for overwintering in manmade orchards and amongst invasive fruiting plants (ie, Chinese tallow, honeysuckle bushes), which are unlikely to experience negative effects as a result of climate change (Finch et al. 2021).	**-1**
5. Habitat quality and reproduction	Are features of the habitat associated with better reproductive success expected to change?	Vanderhoff et al. do not indicate any habitat features that would lead to differentiated reproductive success (2020).	**0**
6. Habitat quality and survival	Are features of the habitat associated with better survival expected to change?	Habitat features associated with better survival rates were not identified. Studies comparing robin abundance in natural riparian habitats versus developed urban areas indicated little difference in survival (Tewksbury et al. 2002).	**0**
7. Ability to colonize new areas	What is this species' capacity and tendency to disperse?	Birds are considered to be quite mobile due to their ability to fly, and thus capable of colonizing new areas. This is especially true for migratory species such as the American robin.	**-1**
8. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and nonbreeding habitats?	No additional habitats were identified.	**0**

AMERICAN ROBIN (*Turdus migratorius*) – PHYSIOLOGY

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Physiological thresholds	Are physiological thresholds related to temperature or moisture expected to change?	Vanderhoff et al. do not provide information on the metabolism and temperature regulation of American robins. No information regarding temperature tolerance of American robins was found in the Web of Science and Google Scholar databases. However, because they are a widely distributed species that live at least part-time in relatively cold and warm conditions (Northern Alaska to parts of the Yucatan Peninsula), it can be assumed that this species can tolerate an increase in temperature several degrees Celsius.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No. There is no current evidence which suggests that incubation temperature influences the sex ratio of birds, with the exception of some megapodes (Göth and Booth 2005).	**0**
3. Exposure to extreme weather conditions	Are extreme weather or disturbance events that result in direct mortality or reproductive failure expected to change?	An increase in the frequency and severity of wildfires is predicted to occur throughout much of the western United States, including in the Rocky Mountains. Mass die-offs of migratory bird species in North America is thought to be linked to habitat loss and poor air quality induced by wildfires (Yang et al. 2021). Additionally, the magnitude of storms are projected to intensify under climate change, which may be linked to an increase in migrant mortality (Newton 2007).	**1**
4. Limitations to active period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	American robins are primarily diurnal and forage for earthworms, fruits, insects, and other arthropods during the day (Vanderhoff et al. 2020). There is no information suggesting that changes in temperature or precipitation would impede upon active periods to the point of significantly reducing species survival.	**0**
5. Metabolic inhibition	Does this species possess an ability to reduce metabolic energy or water requirements?	It is assumed that American robins are not capable of entering torpor based on a lack of documentation, however torpor in general is poorly understood in avian species (Schleucher 2004).	**1**
6. Survival during resource	Does this species have lower energy	American robins are not known to store food (Vanderhoff et al. 2020).	**1**

limitation	requirements or possess the capacity to store energy or water in the long term?		
7. Variable life history	Does this species have alternative life history strategies to cope with variable resources or climate conditions?	Variable life history strategies in this species have not been documented.	**0**
8. Reproduction in variable environments	Can this species outlive periods where reproduction is limited?	The life expectancy of American robins is generally considered to be two years of age, however records from banded birds indicate they can potentially live up to 13 years of age (Vanderhoff et al. 2020). Periods of extreme drought in the western United States can last up to four years (Van Loon et al. 2016). If these conditions reduced resources to the degree that this species is unable to reproduce, then it is likely that only a small fraction of the population may outlive unfavorable conditions.	**1**

AMERICAN ROBIN (*Turdus migratorius*) – PHENOLOGY

Trait/Quality	Question	Background information & explanation of score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival?	American robins typically arrive at their breeding grounds in early spring. Because they are predictable breeders, photoperiod – not temperature or moisture – is thought to be a fundamental proximate factor in the reproduction cycle of birds (Gwinner 2003). However, some evidence suggests that robin populations in the Rocky Mountains may use temperature as a cue to move to breeding grounds at high elevations. Robins in the Rocky Mountains arrive at their breeding grounds two weeks earlier than lower elevation populations, which often occurs before snow has melted and makes it difficult to locate food (Inouye et al. 2000). This is thought to be in response to climate at lower elevations.	**0**
2. Event timing	Are activities related to species' fecundity or	Bird fecundity in the spring is largely compelled by food availability (Martin 1987). The onset of spring is tied to an increase in the abundance of insects, which is a significant	**1**

	survival tied to discrete events that are expected to change?	food source for many avian species, including robins. The emergence of insects is often dependent upon temperature and precipitation cues, so climate-induced changes may shift the timing of food availability and, consequently, bird fecundity.	
3. Mismatch potential	What is the separation in time or space between cues that initiate activities and discrete events that provide critical resources?	American robins are a migratory species; their overwintering and breeding grounds are completely spatially separated. Thus, individuals must commence migration with no information regarding the availability of critical resources on outlying breeding grounds.	**1**
4. Resilience to timing mismatches during breeding	Does this species employ strategies or have traits that increase the likelihood of reproduction co occurring with important events?	American robins regularly rear two broods per season, and occasionally will attempt a third (Vanderhoff et al. 2020).	**0**

AMERICAN ROBIN (*Turdus migratorius*) – BIOTIC INTERACTIONS

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	American robins feed on a variety of animal and plant matter, typically consuming fruits, soft-bodied invertebrates, and hard-bodied invertebrates (White and Stiles 1990). They regularly eat earthworms, grasshoppers, caterpillars, beetles, and wild berries and fruits. Of 1,169 analyzed robins, Wheelwright found that their stomach contents represented over 50 genera of fruits and over 100 families of invertebrates, demonstrating an incredible variety in diet (1986). Robins have also been observed consuming other unusual items, such as frogs, skinks, small snakes, mollusks, and fish (Vanderhoff et al. 2020). As discussed in Question 4, drier conditions will likely reduce the number of native fruiting plant species, however this is unlikely to cause widespread harm to American robin populations due to their adaptability and vast diet.	**0**
2. Predators	Are important	American robins have a number of nest predators, including	**0**

	predator populations expected to change?	jays and crows, snakes, squirrels, cats, martens, and weasels (Vanderhoff et al. 2020). Some mammals, such as foxes, dogs, and raccoons, are more likely to take juvenile birds from the ground while they are still fledging (Pettingill 1976). Raptorial birds are also a major predator of American robins, and 28 species have been recorded hunting robins, including most *Accipiter* hawks, falcons such as the American kestrel and gyrfalcon, and a number of owl species including the snowy owl and the northern pygmy owl (Bent 1938).	
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts are known for the American robin.	**0**
4. Disease	Is the prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Vanderhoff et al. document a number of diseases and parasites that affect the American robin, including tuberculosis, avian pox, lice, ticks, and internal worms (2020). Robins are also a known host and reservoir of West Nile virus because the mosquito vector preferentially feeds on American robins (Simpson et al. 2009). Although this has caused some regional declines, especially in the northeastern United States, there is no evidence to suggest that American robin populations as a whole are declining due to exposure to West Nile virus (Foppa et al. 2011).	**0**
5. Competitors	Are populations of important competing species expected to change?	American robin nests are occasionally parasitized by brown-headed cowbirds. However, in both wild and captive populations, robins are almost always able to recognize and reject cowbird eggs due to their shape (Cruz and Cooper 2001, Underwood and Sealy 2006). There are very few reported observations of American robins rearing a brown-headed cowbird chick (Vanderhoff et al. 2020). Otherwise, no significant competitor species were identified (Vanderhoff et al. 2020).	**0**

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BLACK-CAPPED CHICKADEE (*Poecile atricapillus*) – HABITAT

Trait/Quality	Question	Background information & explanation of score	Points
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	The black-capped chickadee occurs year-round throughout much of the northern United States and Canada. They reside primarily in deciduous and mixed forests, or in thickets of willow and cottonwood species (Foote et al. 2010). This species preferentially selects for nesting and foraging sites in areas with old tree canopies (Grubb and Bronson 2001) and they populate mostly woodland edges. Black-capped chickadees are also capable of surviving in disturbed areas, including in suburban regions, provided that there is adequate foliage for foraging (Foote et al. 2010). There is some evidence to suggest that black-capped chickadees can move vertically within their ranges, however they are often elevationally restricted by other chickadee species, including the Carolina chickadee (lower elevations) and the mountain chickadee (higher elevations; Smith and Van Buskirk 1998). Because woodland habitat types are projected to decrease with climate change, it is likely that suitable chickadee habitat will also decrease.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as breeding habitat, see question 1 above.	**1**
3. Habitat components : *breeding*	Are specific habitat components required for breeding expected to change?	Black-capped chickadees are cavity nesters, and a breeding pair will begin nest excavation approximately 1-2 weeks before egg laying (Foote et al. 2010). In British Columbia, cavities are most frequently excavated in birch, aspen, and maple trees at any height. 87% of chickadee nests were in excavated cavities, whereas the remaining 13% nested in preexisting natural holes (Aitken and Martin 2007).	**1**

		The presence of softwood tree species is projected to decline in response to increased wildfire.	
4. Habitat components: *nonbreeding*	Are specific habitat components required for survival during non-breeding periods expected to change?	No habitat components necessary for the non-breeding period have been identified.	**0**
5. Habitat quality and reproduction	Are features of the habitat associated with better reproductive success expected to change?	There is no information that indicates differentiated reproductive success due to habitat features. Black-capped chickadees can excavate nests between 0 and 20 meters in a tree, however no relationship between nest success and height has been documented (Christman and Dhont 1997).	**0**
6. Habitat quality and survival	Are features of the habitat associated with better survival expected to change?	Habitat features associated with better survival rates were not identified.	**0**
7. Ability to colonize new areas	What is this species' capacity and tendency to disperse?	Birds are considered to be quite mobile due to their ability to fly, and thus capable of colonizing new areas.	**-1**
8. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and nonbreeding habitats?	Black-capped chickadees are not known to migrate long distances, and instead are year-round residents (Foote 2010).	**0**

BLACK-CAPPED CHICKADEE (*Poecile atricapillus*) – PHYSIOLOGY

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1.	Are physiological	Black-capped chickadees are proficient at thermoregulation	**0**

Physiological thresholds	thresholds related to temperature or moisture expected to change?	in cold temperatures, and can induce a state of nocturnal hypothermia to save energy during cold spells (Foote et al. 2010). No information regarding the upper end of temperature tolerance for black-capped chickadees was found in the Web of Science and Google Scholar databases. However, because they are a widely distributed, nonmigratory species, it can be assumed that this species can tolerate an increase in temperature several degrees Celsius.	
2. Sex ratio	Is sex ratio determined by temperature?	No. There is no current evidence which suggests that incubation temperature influences the sex ratio of birds, with the exception of some megapodes (Göth and Booth 2005).	**0**
3. Exposure to extreme weather conditions	Are extreme weather or disturbance events that result in direct mortality or reproductive failure expected to change?	Drier conditions and increase in wildfires are projected for the western United States. One study examined the difference in relative abundance of bird species in tree stands in the Rocky Mountains that had been burned, logged, or untouched. Black-capped chickadees showed a similar abundance across all three stand types (Smith et al. 2007). Direct mortality or reproductive failure from wildfires seems unlikely in this species. Because black-capped chickadees are nonmigratory, they are less likely to suffer increased mortality rates from wildfire smoke and more severe storms (Newton 2007).	**0**
4. Limitations to active period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Black-capped chickadees are primarily diurnal and forage for a variety of insects, larvae, seeds, and berries during the day (Foote et al. 2010). There is no information suggesting that changes in temperature or precipitation would impede upon active periods to the point of significantly reducing species survival.	**0**
5. Metabolic inhibition	Does this species possess an ability to reduce metabolic energy or water requirements?	Black-capped chickadees are capable of dropping their body temperature by 10-12 degrees Celsius during cold nights (Chaplin 1967). This induced nocturnal hypothermia saves a significant amount of energy consumption.	**-1**
6. Survival during	Does this species have lower	This species is notable for its caching tendencies and corresponding spatial memory. Chickadees will cache food	**-1**

resource limitation	energy requirements or possess the capacity to store energy or water in the long term?	predominantly in the autumn, but some individuals do so throughout the year as well (Foote et al. 2010). Caches consist of approximately 64% seeds and 33% insects, and caching sites make use of bark, leaves, and snow away from forest edges (Hitchcock and Sherry 1990). Food storage is thought to be linked to overwinter survival, and black-capped chickadees can accurately recover food after up to 28 days of storage (Foote et al. 2010).	
7. Variable life history	Does this species have alternative life history strategies to cope with variable resources or climate conditions?	Variable life history strategies in this species have not been documented.	**0**
8. Reproduction in variable environments	Can this species outlive periods where reproduction is limited?	The average life expectancy of black-capped chickadees is typically less than two or three years, however some banded birds have been recorded at 11 and 12 years of age, though this is rare (Foote et al. 2010). Periods of extreme drought in the western United States can last up to four years (Van Loon et al. 2016). If these conditions reduced resources to the degree that this species is unable to reproduce, then it is likely that most of the breeding population would not outlive the duration of unfavorable conditions.	**1**

BLACK-CAPPED CHICKADEE (*Poecile atricapillus*) – PHENOLOGY

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival?	Black-capped chickadees typically nest between late April and June. Because they are predictable breeders, photoperiod – not temperature or moisture – is thought to be a fundamental proximate factor in the reproduction cycle of birds (Gwinner 2003). It is suspected that nonmigratory bird species are more sensitive to local temperature cues, however evidence suggests that reproductive behaviors are first triggered by a photoperiod cue and are then supplemented by temperature cues (Martin et al. 2020).	**0**

2. Event timing	Are activities related to species' fecundity or survival tied to discrete events that are expected to change?	Bird fecundity in the spring is largely compelled by food availability (Martin 1987). The onset of spring is tied to an increase in the abundance of insects, which is a significant food source for many avian species. The emergence of insects is often dependent upon temperature and precipitation cues, so climate-induced changes may shift the timing of food availability and, consequently, bird fecundity.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities and discrete events that provide critical resources?	This species is a year-round resident. Increases in critical resources (e.g. food) occur in spring, so there is little temporal separation. There is no spatial separation because chickadees are nonmigratory.	**-1**
4. Resilience to timing mismatches during breeding	Does this species employ strategies or have traits that increase the likelihood of reproduction co occurring with important events?	Pairs of black-capped chickadees typically rear one brood per season and will attempt replacement broods if their first clutch fails. True second broods are rarely observed (Foote et al. 2020).	**1**

BLACK-CAPPED CHICKADEE (*Poecile atricapillus*) – BIOTIC INTERACTIONS

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	This species consumes a variety of insects and plants. During the breeding season, their diet consists mainly of caterpillars, but also includes spiders, snails, slugs, blackberries, honeysuckle, and blueberries. During the nonbreeding season, they incorporate more plant matter into their diet, including seeds from weeds and conifers, soft fruits like wild cherries, and small berries (Foote et al. 2010). There are also reports of chickadees taking the eggs of other bird species and consuming fat from dead vertebrates such as deer and fish (Smith 1991).	**0**
2. Predators	Are important predator	Adult black-capped chickadees are frequently depredated by other birds, including sharp-shinned hawks, northern	**0**

	populations expected to change?	shrikes, easter screech owls, and northern saw-whet owls (Foote et al. 2010). This species also has a number of nest predators that either consume or destroy eggs and hatchlings, including snakes, racoons, opossums, and house wrens (Foote et al. 2010).	
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts are known for the black-capped chickadee.	**0**
4. Disease	Is the prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Foote et al. reports a number of different parasites and diseases, however none appear to have significant negative impact on black-capped chickadee populations (2010). Some populations of black-capped chickadees in Alaska suffer from avian keratin disorder, which results in beak deformities and elongated mandibles that reduce fitness (Zylberberg et al. 2018). However, outside of a select few populations, this does not appear to cause significant mortality.	**0**
5. Competitors	Are populations of important competing species expected to change?	Black-capped chickadees compete with other chickadee species for food and foraging sites, as well as other cavity nesters (eastern bluebirds, tree swallows, house sparrows, house wrens) for nest sites (Foote et al. 2010). At least some of these competitor species are likely vulnerable to climate change. Brood parasitism is rarely documented in this species (Foote et al. 2010).	**-1**

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YELLOW WARBLER (*Setophaga petechia*) – HABITAT

Trait/Quality	Question	Background information & explanation of score	Points
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Yellow warblers are widely distributed throughout North America and make use of a number of habitat types for breeding; for this reason, they are broadly considered to be habitat generalists. They are most frequently observed in deciduous thickets where the dominant shrubs are willows, and they will preferentially select nesting sites in copses comprised of willow, alder, and/or dogwood species (Lowther et al. 2020). They typically use riparian zones for both nesting and foraging, however breeding populations have persisted in both wet and dry climates from Manitoba to Arizona (Small 1994). They do not appear to be limited by elevation; they have been documented between 100 and 2700 meters in riparian areas in California and Arizona, and singing males have been reported in montane forests above 300 meters in the West Indies (Small 1994, Raffaele et al. 1998). Although current climate models predict a drying of wetlands and the loss of *Salix* species (Desta et al. 2012), yellow warblers are adaptable and can successfully breed in both urban habitats and open grasslands. In British Columbia, successful nest sites have been observed in altered environments, including highly-cultivated farmlands and orchards, urban parks, roadsides, and on overhead power lines (Campbell et al. 2001). In Ontario, breeding populations of yellow warblers have been recorded in pastures and fields, as well as open temperate grasslands (Lowther et al. 2020). A study done on Maine's coastal islands even found that small populations of yellow warblers were capable of propagating in mature spruce forests when other warbler species were not present (Morse 1973). It is likely that yellow warblers will adapt to modified habitats regardless of shrinking riparian zones.	**0**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected	This species demonstrates a similar propensity for most any habitat type in overwintering grounds. Yellow warblers have been observed in both wet and dry scrublands, backyard gardens, urban parks and town centers, woody marshlands, open pastures with some brush, riparian forests, and agricultural farmland (Lowther et al. 2020). This species is also notable for overwintering in mangrove swamps in Mexico (Dunn and Garrett 1997).	**0**

	to change?	Drier conditions are expected to occur in nonbreeding grounds, however there is little difference in the mortality of yellow warblers that live in forested habitats as opposed to human-influenced urban habitats (Lowther et al. 2020).	
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change?	Yellow warblers require some trees or shrubs in order to nest. They typically build nests in the fork of an upright shrub, tree, or sapling, approximately 2-5 meters off the ground in *Salix* species (Lowther et al. 2020). Overall, drier conditions will likely lead to a reduction in tree species, and therefore a reduction in potential nesting sites for breeding warblers.	**1**
4. Habitat components: *nonbreeding*	Are specific habitat components required for survival during non-breeding periods expected to change?	Habitat components required for survival in the nonbreeding season were not identified.	**0**
5. Habitat quality and reproduction	Are features of the habitat associated with better reproductive success expected to change?	Lowther et al. do not indicate any habitat features that would lead to differentiated reproductive success (2020). However, some evidence exists which suggests that yellow warblers that overwinter on agricultural scrublands produce 0.8 more fledglings than those that overwinter in riparian forest zones (Drake et al. 2013). It is unclear if this would be a net benefit for populations subject to habitat modification.	**0**
6. Habitat quality and survival	Are features of the habitat associated with better survival expected to change?	Habitat features associated with better survival rates were not identified.	**0**
7. Ability to colonize new areas	What is this species' capacity and tendency to disperse?	Birds are considered to be quite mobile due to their ability to fly, and thus capable of colonizing new areas. This is especially true for migratory species such as the yellow warbler.	**-1**
8. Migratory or transitional habitats	Does this species require additional	This species migrates long distances and often utilizes forest edges and barrier islands on the Gulf Coast as stopover sites (Lowther et al. 2020). These are areas likely to be threatened	**1**

	habitats during migration that are separated from breeding and nonbreeding habitats?	by warming climate and rising sea levels.	

YELLOW WARBLER (*Setophaga petechia*) – PHYSIOLOGY

Trait/Quality	Question	Background information & explanation of score	Points
1. Physiological thresholds	Are physiological thresholds related to temperature or moisture expected to change?	Lowther et al. do not provide information on the metabolism and temperature regulation of yellow warblers. No information regarding temperature tolerance of yellow warblers was found in the Web of Science and Google Scholar databases. However, because they are a widely distributed species that live at least part-time in relatively cold and warm conditions (Aleutian Islands to Neotropics), it can be assumed that this species can tolerate an increase in temperature several degrees Celsius.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No. There is no current evidence which suggests that incubation temperature influences the sex ratio of birds, with the exception of some megapodes (Göth and Booth 2005).	**0**
3. Exposure to extreme weather conditions	Are extreme weather or disturbance events that result in direct mortality or reproductive failure expected to change?	An increase in the frequency and severity of wildfires is predicted to occur throughout much of the western United States, including in the Rocky Mountains. Mass die-offs of migratory bird species in North America is thought to be linked to habitat loss and poor air quality induced by wildfires (Yang et al. 2021). Additionally, the magnitude of storms are projected to intensify under climate change, which may be linked to an increase in migrant mortality (Newton 2007).	**1**
4. Limitations to active period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Yellow warblers are primarily diurnal and forage for a variety of insects and arthropods during the day (Lowther et al. 2020). There is no information suggesting that changes in temperature or precipitation would impede upon active periods to the point of significantly reducing species survival.	**0**

5. Metabolic inhibition	Does this species possess an ability to reduce metabolic energy or water requirements?	Lowther et al. do not report any information on the nutrition and energetics of this species (2020). It is assumed that yellow warblers are not capable of entering torpor based on a lack of documentation, however torpor in general is poorly understood in avian species (Schleucher 2004).	**1**
6. Survival during resource limitation	Does this species have lower energy requirements or possess the capacity to store energy or water in the long term?	Yellow warblers are not known to store food (Lowther et al. 2020).	**1**
7. Variable life history	Does this species have alternative life history strategies to cope with variable resources or climate conditions?	Variable life history strategies in this species have not been documented.	**0**
8. Reproduction in variable environments	Can this species outlive periods where reproduction is limited?	The life expectancy of yellow warblers varies, however records from banded birds indicate they can potentially live up to 8-10 years of age (Lowther et al. 2020). Periods of extreme drought in the western United States can last up to four years (Van Loon et al. 2016). If these conditions reduced resources to the degree that this species is unable to reproduce, then it is possible that a sufficient number of individuals may survive to recover the population.	**-1**

YELLOW WARBLER (*Setophaga petechia*) – PHENOLOGY

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related	Yellow warblers typically arrive at their breeding grounds in late spring. Because they are predictable breeders, photoperiod – not temperature or moisture – is thought to be a fundamental proximate factor in the reproduction cycle of birds (Gwinner 2003).	**0**

	to fecundity or survival?	However, this species exhibits considerable plasticity in the timing of the initiation of their clutch. Mazerolle et al. found a strong correlation between the mean May temperatures of the breeding site and the clutch initiation response in yellow warblers (2010). This suggests that yellow warblers may rely on temperature in order to lay eggs.	
2. Event timing	Are activities related to species' fecundity or survival tied to discrete events that are expected to change?	Bird fecundity in the spring is largely compelled by food availability (Martin 1987). The onset of spring is tied to an increase in the abundance of insects, which is a significant food source for many avian species. The emergence of insects is often dependent upon temperature and precipitation cues, so climate-induced changes may shift the timing of food availability and, consequently, bird fecundity.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities and discrete events that provide critical resources?	Yellow warblers are a migratory species; their overwintering and breeding grounds are completely spatially separated. Thus, individuals must commence migration with no information regarding the availability of critical resources on faraway breeding grounds.	**1**
4. Resilience to timing mismatches during breeding	Does this species employ strategies or have traits that increase the likelihood of reproduction co occurring with important events?	Yellow warbler pairs typically rear one brood per season; rarely will they attempt a second (Lowther et al. 2020).	**1**

YELLOW WARBLER (*Setophaga petechia*) – BIOTIC INTERACTIONS

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Food resources	Are important food resources for this species	An estimated 60% of a yellow warbler's diet consists of caterpillars. However, this species also consumes a variety of insects and arthropods, including midges, beetles, true bugs,	**0**

	expected to change?	wasps, and spiders (Lowther et al. 2020). In the winter season, they have also been observed foraging for small fruits (Campbell et al. 2001). Overall, this species has a varied diet.	
2. Predators	Are important predator populations expected to change?	Yellow warblers are preyed upon by many predators. Corvids (American crow, gray jay), snakes (garter snakes, blue racer), and large climbing rodents (squirrels, weasels, raccoons, foxes, cats) are all significant nest predators. Some avian predators, including sharp-shinned hawks, merlins, and eastern screech owls, have also been observed attacking adult and subadult yellow warblers (Lowther et al. 2020).	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts are known for the yellow warbler.	**0**
4. Disease	Is the prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Lowther et al. document two species of Mallophaga (lice) in yellow warblers, however no information indicates significant negative impact on populations. Avian pox and avian malaria have been documented in yellow warblers in the Galapagos, but these diseases are not well studied in the western United States (Jenkins et al. 2021)	**0**
5. Competitors	Are populations of important competing species expected to change?	Yellow warblers are frequently parasitized by brown-headed cowbirds. If nest parasitism is detected by the brooding female, she will build a new nest over the parasitized clutch or abandon her nest. This results in loss of warbler eggs and reduced clutch sizes; parasitized nests produce an average of 0.7 young per nest, while non-parasitized nests produce an average of 1.8 young per nest (Lowther et al. 2020). It is likely that the pressure of cowbird parasitism will continue to intensify as yellow warblers respond to other factors of climate change.	**1**

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<u>SPECIALISTS</u>
AMERICAN PIPIT (*Anthus rubescens*) – HABITAT

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	The American pipit is a migratory North American songbird that breeds at high elevations. They can be found in the treeless tundra zones of northern Alaska, eastern Newfoundland, on mountain tops in New England, and across barren coastlines in Labrador (Hendricks and Verbeek 2020). Pipits often occupy alpine meadows consisting of sedges, dwarf willows, and hairgrasses, as well as lofty boulder fields containing various cushion plant species (Kingrey 1998). In alpine habitat, they typically breed in high moisture conditions, while in arctic habitat, they prefer drier conditions (Johnsgard 1979). They are found at approximately 3,000 meters. American pipits have been observed successfully breeding in human-altered agricultural lands, however these pastures were still on mountain slopes at high altitude (Hendricks and Verbeek 2020). Increasing temperatures and changes to moisture and precipitation will likely cause plant species assemblages to shift in response to climate change. Trees and shrubs are already moving uphill, and they are likely to encroach upon arctic zones and outcompete resident species (Seastedt and Oldfather 2021).	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	The American pipit overwinters on coastal beaches, along flowing lowland rivers, near high-elevation lakes, and sometimes in farmyards or recently-plowed fields. Large flocks frequently occur in open, damp areas such as mud flats or marshes (Bent 1950). The American pipit can migrate as far south as the United States southwest and Mexico, however habitat selection in these regions is not well understood (Hendricks and Verbeek 2020). Unlike other species of open country birds, American pipits are thought to preferentially select overwintering grounds with higher moisture presence (Hendricks and Verbeek 2020). Drier conditions will likely lead to a reduction of suitable nonbreeding habitat for this species.	**1**
3. Habitat components:	Are specific habitat	American pipits are ground nesters, and they will line a small, recessed hollow with grasses and twigs. These nest sites do not	**-1**

breeding	components required for breeding expected to change?	become available in high elevation sites until summer, when the snow and meltwater have disappeared (Hendricks and Verbeek 2020). Warmer conditions would likely lead to an increase in the availability of nest sites at an earlier time of the year, which may be beneficial to this species.	
4. Habitat components: *nonbreeding*	Are specific habitat components required for survival during non-breeding periods expected to change?	Habitat components required for survival in the nonbreeding season were not identified. American pipits are thought to preferentially select wetter habitats for overwintering (see question 2), however it is unclear if there is a link between this preference and survivorship (Hendricks and Verbeek 2020).	**0**
5. Habitat quality and reproduction	Are features of the habitat associated with better reproductive success expected to change?	Hendricks and Verbeek do not indicate any habitat features that would lead to differentiated reproductive success (2020).	**0**
6. Habitat quality and survival	Are features of the habitat associated with better survival expected to change?	Habitat features associated with better survival rates were not identified.	**0**
7. Ability to colonize new areas	What is this species' capacity and tendency to disperse?	Birds are considered to be quite mobile due to their ability to fly, and thus capable of colonizing new areas. This is especially true for migratory species such as the American pipit.	**-1**
8. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and nonbreeding habitats?	American pipits use additional habitats during migration that are similar to their overwintering grounds (see question 2). However, in general, the characteristics and selection of stopover sites used by American pipits are understudied (Hendricks and Verbeek 2020).	**1**

AMERICAN PIPIT (*Anthus rubescens*) – PHYSIOLOGY

Trait/Quality	Question	Background information & explanation of score	Points
1. Physiological thresholds	Are physiological thresholds related to temperature or moisture expected to change?	Hendricks and Verbeek do not provide information on the metabolism and temperature regulation of American pipits (2020). No information regarding temperature tolerance of American pipits was found in the Web of Science and Google Scholar databases. However, because they are a high-elevation specialist that cannot adapt to warming temperatures by retreating upwards, it is likely that this species will not tolerate increases in average temperature very well.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No. There is no current evidence which suggests that incubation temperature influences the sex ratio of birds, with the exception of some megapodes (Göth and Booth 2005).	**0**
3. Exposure to extreme weather conditions	Are extreme weather or disturbance events that result in direct mortality or reproductive failure expected to change?	An increase in the frequency and severity of wildfires is predicted to occur throughout much of the western United States, including in the Rocky Mountains. Mass die-offs of migratory bird species in North America is thought to be linked to habitat loss and poor air quality induced by wildfires (Yang et al. 2021). Additionally, the magnitude of storms are projected to intensify under climate change, which may be linked to an increase in migrant mortality (Newton 2007).	**1**
4. Limitations to active period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	American pipits are primarily diurnal, but they will forage alone during all hours of the day during breeding season, and in loosely-cooperative flocks during overwintering periods (Hendricks and Verbeek 2020). There is no information suggesting that changes in temperature or precipitation would impede upon active periods to the point of significantly reducing species survival.	**0**
5. Metabolic inhibition	Does this species possess an ability to reduce metabolic energy or water requirements?	Hendricks and Verbeek do not report any information on the nutrition and energetics of this species (2020). It is assumed that American pipits are not capable of entering torpor based on a lack of documentation, however torpor in general is poorly understood in avian species (Schleucher 2004).	**1**
6. Survival	Does this	American pipits are not known to store food (Hendricks and	**1**

during resource limitation	species have lower energy requirements or possess the capacity to store energy or water in the long term?	Verbeek 2020).	
7. Variable life history	Does this species have alternative life history strategies to cope with variable resources or climate conditions?	Variable life history strategies in this species have not been documented.	**0**
8. Reproduction in variable environments	Can this species outlive periods where reproduction is limited?	The life expectancy of American pipits is not well-documented, however records from a bird banding operation found one individual that was at least 5 years old (Hendricks and Verbeek 2020). Periods of extreme drought in the western United States can last up to four years (Van Loon et al. 2016). If these conditions reduced resources to the degree that this species is unable to reproduce, then it is likely that very little of the population may outlive unfavorable conditions, if at all.	**1**

AMERICAN PIPIT (*Anthus rubescens*) – PHENOLOGY

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival?	American pipits typically arrive at their breeding grounds in early summer, usually around the end of April or beginning of May. Because they are predictable breeders, photoperiod – not temperature or moisture – is thought to be a fundamental proximate factor in the reproduction cycle of birds (Gwinner 2003).	**0**
2. Event timing	Are activities related to species' fecundity or	Bird fecundity in the spring is largely compelled by food availability (Martin 1987). The onset of spring is tied to an increase in the abundance of insects, which is a significant food source for many avian species. The emergence of insects	**1**

	survival tied to discrete events that are expected to change?	is often dependent upon temperature and precipitation cues, so climate-induced changes may shift the timing of food availability and, consequently, bird fecundity.	
3. Mismatch potential	What is the separation in time or space between cues that initiate activities and discrete events that provide critical resources?	American pipits are a migratory species; their overwintering and breeding grounds are completely spatially separated. Thus, individuals must commence migration with no information regarding the availability of critical resources on faraway breeding grounds.	**1**
4. Resilience to timing mismatches during breeding	Does this species employ strategies or have traits that increase the likelihood of reproduction co occurring with important events?	Female American pipits may lay a replacement clutch of eggs if her first was destroyed, however pairs will only raise one brood per year (Hendricks and Verbeek 2020).	**1**

AMERICAN PIPIT (*Anthus rubescens*) – BIOTIC INTERACTIONS

Trait/Quality	Question	Background information & explanation of score	Points
1. Food resources	Are important food resources for this species expected to change?	The American pipit is an insectivorous species that consumes terrestrial and freshwater invertebrates. During the summer months, nearly all of their diet is made up of animal matter, however they consume a variety of arthropods and insects, including spiders, butterflies, moths, grasshoppers, ants, beetles, and mites (Hendricks and Verbeek 2020). They have been observed wading into shallow pools to consume aquatic insects and their larvae (eg, caddisflies and mayflies), as well as marine worms and small crustaceans (Miller 1988). They have also been observed eating the seeds of plants on occasion, usually during the autumn and winter seasons (Bent 1950).	**0**

2. Predators	Are important predator populations expected to change?	Adult pipits are hunted by a variety of raptorial birds, including the American kestrel, merlin, peregrine falcon, rough-legged hawk, barn owl, short-eared owl, and occasionally ravens. Adults and nestlings will also sometimes be killed by coyotes, badgers, and red foxes (Hendricks and Verbeek 2020). Common nest predators include red foxes, long-tailed weasels, deer mice, ground squirrels, and ravens (Hendricks and Norment 1992).	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts are known for the American pipit.	**0**
4. Disease	Is the prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	A number of diseases and parasites have been documented in American pipits, including roundworms, feather and nasal mites, and lice (Hendricks and Verbeek 2020). However, no information indicates significant negative impact on populations.	**0**
5. Competitors	Are populations of important competing species expected to change?	American pipits often compete with other high-elevation breeding birds for nesting sites, including horned larks, lapland longspurs, and rosy finch species (Hendricks and Verbeek 2020). Because these species all occupy a similar ecological niche and rely on many of the same resources, it is unlikely that climate change factors will benefit one species but not the others. Pipit nestlings are also sometimes parasitized by blowflies. However, this is rare and typically does not result in significant nestling mortality (Sabrosky et al. 1989).	**0**

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GRAY-CROWNED ROSY-FINCH (*Leucosticte tephrocotis*) – HABITAT

Trait/Quality	Question	Background information & explanation of score	Points
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	The gray-crowned rosy-finch is a migratory songbird found in extreme mountain environments. They are found throughout the Cascades, Rocky Mountain, and Sierra Nevada mountain ranges, and have also been observed in the coastal mountain habitats of the Aleutian Islands (MacDougall-Shackleton et al. 2020). It is thought to be the highest-altitude breeding bird in North America, spending much of its time above the timberline in alpine areas (Bent 1968). Rosy-finch nests have been described in a number of montane locations, including glaciers, windswept screes, cliffs, rock piles, avalanche chutes, and snow fields (Johnson 1975). Because of the remote, inaccessible nature of their habitat, gray-crowned rosy-finches are largely understudied. Specific habitat components and preferences for habitat features are poorly understood (MacDougall-Shackleton et al. 2020). Rosy-finches are likely reliant upon the presence of alpine grasses, sedges, and mosses to utilize in nest-building activities (MacDougall-Shackleton et al. 2020). The warmer temperatures and differing moisture regimes that result from climate change allow lower-elevation species to encroach upon high-altitude habitats and reshape these environments. Trees and shrubs frequently outcompete resident species in high elevation communities, which may be detrimental to rosy-finch populations (Seastedt and Oldfather 2021).	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Many populations of gray-crowned rosy-finches disperse to lower elevations during the winter. In the Rocky Mountains, they move downslope toward valleys, and they have been documented in hillsides and meadows, dry ditches, shrublands, and occasionally within towns or along roadsides (MacDougall-Shackleton et al. 2020). They typically favor wide open areas wherever food is accessible, and often only move low enough to avoid heavy snowfall during severe winter storms (Johnson 1965). Much like their breeding habitat, the specific preferences of rosy-finches in overwintering grounds are not well-documented.	**1**
3. Habitat components:	Are specific habitat	Habitat components required for survival in the breeding season were not identified.	**0**

breeding	components required for breeding expected to change?		
4. Habitat components: *nonbreeding*	Are specific habitat components required for survival during non-breeding periods expected to change?	Habitat components required for survival in the nonbreeding season were not identified.	**0**
5. Habitat quality and reproduction	Are features of the habitat associated with better reproductive success expected to change?	Habitat features that would lead to differentiated reproductive success were not identified.	**0**
6. Habitat quality and survival	Are features of the habitat associated with better survival expected to change?	Although no formal studies have been conducted on the subject, gray-crowned rosy-finches reportedly prefer to forage near glaciers or in snow fields (Twining 1940, Bent 1968, Johnson 1975). Glacial recession is a major concern for high-elevation habitats, especially in mountainous regions like the Rockies (Hoffman et al. 2007). This may result in reduced foraging habitat for this species, and, as a result, declining survival.	**1**
7. Ability to colonize new areas	What is this species' capacity and tendency to disperse?	Birds are considered to be quite mobile due to their ability to fly, and thus capable of colonizing new areas. This is especially true for migratory species such as the gray-crowned rosy-finch.	**-1**
8. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and nonbreeding habitats?	Unknown; the characteristics and selection of stopover sites used by gray-crowned rosy-finches is poorly understood.	**0**

GRAY-CROWNED ROSY-FINCH (*Leucosticte tephrocotis*) – PHYSIOLOGY

Trait/Quality	Question	Background information & explanation of score	Points
1. Physiological thresholds	Are physiological thresholds related to temperature or moisture expected to change?	Gray-crowned rosy-finches have the capacity to induce mild nocturnal hypothermia, which allows them to withstand colder temperatures at night (Clemens 1989). Heat tolerance in gray-crowned rosy-finches is understudied. However, because they are a high-elevation specialist that cannot adapt to warming temperatures by retreating upwards, it is likely that this species will not tolerate increases in average temperature very well.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No. There is no current evidence which suggests that incubation temperature influences the sex ratio of birds, with the exception of some megapodes (Göth and Booth 2005).	**0**
3. Exposure to extreme weather conditions	Are extreme weather or disturbance events that result in direct mortality or reproductive failure expected to change?	An increase in the frequency and severity of wildfires is predicted to occur throughout much of the western United States, including in the Rocky Mountains. Mass die-offs of migratory bird species in North America is thought to be linked to habitat loss and poor air quality induced by wildfires (Yang et al. 2021). Additionally, the magnitude of storms are projected to intensify under climate change, which may be linked to an increase in migrant mortality (Newton 2007).	**1**
4. Limitations to active period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Gray-crowned rosy-finches are a diurnal species of bird, and they forage for a variety of plant matter and insects during the day (MacDougall-Shackleton et al. 2020). There is no information suggesting that changes in temperature or precipitation would impede upon active periods to the point of significantly reducing species survival.	**0**
5. Metabolic inhibition	Does this species possess an ability to reduce metabolic energy or water requirements?	MacDougall-Shackleton et al. do not report any information on the nutrition and energetics of this species (2020). It is assumed that gray-crowned rosy-finches are not capable of entering torpor based on a lack of documentation, however torpor in general is poorly understood in avian species (Schleucher 2004).	**1**
6. Survival	Does this	Gray-crowned rosy-finches are not known to store food	**1**

during resource limitation	species have lower energy requirements or possess the capacity to store energy or water in the long term?	(MacDougall-Shackleton et al. 2020).	
7. Variable life history	Does this species have alternative life history strategies to cope with variable resources or climate conditions?	Variable life history strategies in this species have not been documented.	**0**
8. Reproduction in variable environments	Can this species outlive periods where reproduction is limited?	Gray-crowned rosy-finches are believed to live to approximately six to seven years of age according to data from banded populations (MacDougall-Shackleton et al. 2020). Periods of extreme drought in the western United States can last up to four years (Van Loon et al. 2016). If these conditions reduced resources to the degree that this species is unable to reproduce, then it is likely that only a small fraction of the population may outlive unfavorable conditions.	**1**

GRAY-CROWNED ROSY-FINCH (*Leucosticte tephrocotis*) – PHENOLOGY

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival?	Gray-crowned rosy-finches typically begin nest-building activities in the summer, usually by mid-June in the Rocky Mountains (Johnson 1965). Because they are predictable breeders, photoperiod – not temperature or moisture – is thought to be a fundamental proximate factor in the reproduction cycle of birds (Gwinner 2003).	**0**
2. Event timing	Are activities related to species' fecundity or survival tied to	Bird fecundity is largely compelled by food availability (Martin 1987). The onset of summer is tied to an increase in the abundance of seeds in high-elevation habitats, which is a significant food source for this species. The emergence of seeds is often dependent upon temperature and precipitation	**1**

	discrete events that are expected to change?	cues, so climate-induced changes may shift the timing of food availability and, consequently, bird fecundity.	
3. Mismatch potential	What is the separation in time or space between cues that initiate activities and discrete events that provide critical resources?	Increases in critical resources (e.g. food) occur in spring and summer, so there is little temporal separation. Although gray-crowned rosy-finches are migratory, they typically move along an elevational gradient not far from their breeding grounds – this results in little spatial separation (MacDougall-Shackleton et al. 2020).	**-1**
4. Resilience to timing mismatches during breeding	Does this species employ strategies or have traits that increase the likelihood of reproduction co occurring with important events?	Populations of rosy-finches in the Aleutian Islands are documented to have two or three broods per season (MacDougall-Shackleton et al. 2020). However, in montane environments like the Rocky Mountains, they generally have only one brood (Johnson 1965).	**1**

GRAY-CROWNED ROSY-FINCH (*Leucosticte tephrocotis*) – BIOTIC INTERACTIONS

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	The gray-crowned rosy-finch primarily consumes a diet of seeds, however it is known to occasionally take insects and other plant matter during the summer when young require extra food (MacDougall-Shackleton et al. 2020). Rosy-finch populations in the Rocky Mountains eat mostly wild seeds; they chiefly consume seeds of beargrass, willowweed, spring beauty, and Whitelow grass (Johnson 1965). They will sometimes take cutworms during the breeding season, too (MacDougall-Shackleton et al. 2020). An analysis of stomach contents revealed that rosy-finch diets are composed of approximately 90% seeds during the winter, with the remainder being insects (Twining 1940). In alpine meadow habitats, climate change is likely to cause a shift in the distribution and flowering times of many plant	**1**

		species, including those fed upon by the gray-crowned rosy-finch (Dunne et al. 2003). This would likely be detrimental to the ability of this species to find sufficient food sources.	
2. Predators	Are important predator populations expected to change?	Several reports indicate that gray-crowned rosy-finches are frequently taken by larger avian species, including sharp-shinned hawks, gyrfalcons, screech owls, common ravens, and shrikes (Johnson 1965). The golden-mantled ground squirrel and the Clark's nutcracker are also documented nest predators; they will consume or destroy eggs if found in nests (MacDougall-Shackleton et al. 2020).	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts are known for the gray-crowned rosy-finch.	**0**
4. Disease	Is the prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Various diseases and parasites – including mites, avian pox, and ticks – have all been documented in gray-crowned rosy-finches (MacDougall-Shackleton et al. 2020). However, no information indicates significant negative impact on populations.	**0**
5. Competitors	Are populations of important competing species expected to change?	MacDougall-Shackleton et al. do not report any major competitor species for the gray-crowned rosy-finch (2020). This is likely due to their extreme habitat.	**0**

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WHITE-TAILED PTARMIGAN (*Lagopus leucura*) – HABITAT

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	The white-tailed ptarmigan is a North American bird species that frequents alpine habitats. It can be found as far north as the Yukon, on mountain tops throughout the American northwest (especially in the Rocky Mountains and the Cascade Range), and even at high elevations in New Mexico (Martin et al. 2020). They live at or above the treeline on rocky slopes, where they forage among moist vegetation near streams, willow communities, and krummholz (Frederick and Gutierrez 1992). In the summers, they more readily utilize rugged boulder fields as their habitat, while in the winters they prefer stretches of meadow or outcrops with snow patches (Hoffman 2006). This is due to their strong camouflage in respective seasons, which they rely on to avoid predation. This species is not a long-distance migrant, however some populations will move downhill in response to severe cold weather. In the central Rocky Mountains, ptarmigans will move to basins of predominantly willow species for shelter from high winds and heavy snowfall (Martin et al. 2020). Climate change is projected to reduce snowpack at high altitudes and create drier conditions, resulting in the loss of moisture-dependent plant species such as willows and sedges (Cooper et al. 2006). This would likely reduce the scope of suitable habitat for white-tailed ptarmigans, and may even offset their camouflage ability as snow becomes less common.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as breeding habitat, see question 1 above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to	White-tailed ptarmigans nest exclusively on the ground, and females will scratch out a shallow bowl in the dirt encircled by dry vegetation. Most nests are constructed under the shelter of rocks or willow krummholz, and habitat must be free of snow in order to nest (Martin et al. 2020).	**-1**

	change?	Warmer conditions would likely lead to an increase in the availability of nest sites at an earlier time of the year, which may be beneficial to this species.	
4. Habitat components: *nonbreeding*	Are specific habitat components required for survival during non-breeding periods expected to change?	During the winter, white-tailed ptarmigans rely on willow-dominated plant communities to escape from severe weather and heavy snowfall, and for foraging (Martin et al. 2020). Drier conditions will make it difficult for willow species to establish, and lower-elevation plants are expected to move uphill and outcompete resident species in response to climate change (Cooper et al 2006; Seastedt and Oldfather 2021). It is unclear whether the replacement of willow with other species would affect the survival of white-tailed ptarmigans in the winter.	**1**
5. Habitat quality and reproduction	Are features of the habitat associated with better reproductive success expected to change?	Some evidence suggests that ptarmigan nests constructed under the cover of rocks or foliage are more successful because they are more concealed (Wilson and Martin 2008). Drier conditions would lead to the loss of foliage cover, and therefore lower reproductive success as more females must build nests in exposed areas.	**1**
6. Habitat quality and survival	Are features of the habitat associated with better survival expected to change?	Habitat features associated with better survival rates were not identified.	**0**
7. Ability to colonize new areas	What is this species' capacity and tendency to disperse?	Birds are considered to be quite mobile due to their ability to fly, and thus capable of colonizing new areas.	**-1**
8. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and nonbreeding habitats?	White-tailed ptarmigans are not known to migrate long distances, and instead will move along an elevational gradient in their habitat as a response to weather conditions (Martin et al. 2020).	**0**

WHITE-TAILED PTARMIGAN (*Lagopus leucura*) – PHYSIOLOGY

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Physiological thresholds	Are physiological thresholds related to temperature or moisture expected to change?	White-tailed ptarmigans are highly specialized for cold tolerance, and are thermoneutral at temperatures as low as 6 degrees Celsius (Martin et al. 2020). Because of this, these birds are at very high risk for heat stress; their feathers have a high insulation value and they have one of the lowest evaporative cooling efficiencies documented in birds (Johnson 1968). White-tailed ptarmigans have been observed participating in cooling behaviors (ie, snow bathing and gular fluttering) in temperatures above 21 degrees Celsius. Because they are a high-elevation specialist that cannot adapt to warming temperatures by retreating upwards, it is likely that this species will not tolerate increases in average temperature.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No. There is no current evidence which suggests that incubation temperature influences the sex ratio of birds, with the exception of some megapodes (Göth and Booth 2005).	**0**
3. Exposure to extreme weather conditions	Are extreme weather or disturbance events that result in direct mortality or reproductive failure expected to change?	Heat waves and wildfires are predicted to become more frequent and more severe under the current climate model, even at high elevation sites that are considered untouched by anthropogenic influence (Field et al. 2018). White-tailed ptarmigans do not have the capacity to respond to these extreme heat events (see question 1 above), and will likely suffer higher rates of mortality in hotter years, especially because they do not have anywhere uphill to retreat to (Martin et al. 2020).	**1**
4. Limitations to active period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	White-tailed ptarmigan are typically diurnal and forage for plant matter and insects during the day (Martin et al. 2020). There is no information suggesting that changes in temperature or precipitation would impede upon active periods to the point of significantly reducing species survival.	**0**
5. Metabolic inhibition	Does this species possess an ability to reduce metabolic energy or water	It is assumed that white-tailed ptarmigans are not capable of entering torpor based on a lack of documentation, however torpor in general is poorly understood in avian species (Schleucher 2004).	**1**

	requirements?		
6. Survival during resource limitation	Does this species have lower energy requirements or possess the capacity to store energy or water in the long term?	White-tailed ptarmigans can accumulate food in their crop for later digestion, however this is not considered a long-term storage behaviour like caching (Martin et al. 2020).	**1**
7. Variable life history	Does this species have alternative life history strategies to cope with variable resources or climate conditions?	Variable life history strategies in this species have not been documented.	**0**
8. Reproduction in variable environments	Can this species outlive periods where reproduction is limited?	The life expectancy of white-tailed ptarmigans varies based on region and management regimes, but typically averages about three to four years (Sandercock et al 2005). Records from banded birds indicate this species can potentially live up to 15 years of age (Martin et al. 2020). Periods of extreme drought in the western United States can last up to four years (Van Loon et al. 2016). If these conditions reduced resources to the degree that this species is unable to reproduce, then it is likely that only a small fraction of the population may outlive unfavorable conditions.	**1**

WHITE-TAILED PTARMIGAN (*Lagopus leucura*) – PHENOLOGY

Trait/Quality	Question	Background information & explanation of score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival?	White-tailed ptarmigans usually nest during early summer, between the end of April and the start of May. Because they are predictable breeders, photoperiod – not temperature or moisture – is thought to be a fundamental proximate factor in the reproduction cycle of birds (Gwinner 2003).	**0**

2. Event timing	Are activities related to species' fecundity or survival tied to discrete events that are expected to change?	Bird fecundity in the spring is largely compelled by food availability (Martin 1987). The onset of spring is tied to an increase in the abundance of insects, which is a significant food source for many avian species. The emergence of insects is often dependent upon temperature and precipitation cues, so climate-induced changes may shift the timing of food availability and, consequently, bird fecundity.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities and discrete events that provide critical resources?	This species is a year-round resident. Increases in critical resources (e.g. food) occur in spring and summer, so there is little temporal separation. There is little spatial separation because ptarmigans are not long-distance migrants.	**-1**
4. Resilience to timing mismatches during breeding	Does this species employ strategies or have traits that increase the likelihood of reproduction co occurring with important events?	White-tailed ptarmigan pairs raise one brood per year, and will attempt one to two replacement clutches if the first brood is destroyed (Martin et al. 2020). True second broods are not observed.	**1**

WHITE-TAILED PTARMIGAN (*Lagopus leucura*) – BIOTIC INTERACTIONS

Trait/Quality	**Question**	**Background information & explanation of score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	White-tailed ptarmigans eat a variety of items in the summer, including insects, flowers and fruits, seeds, buds, stems, and leaves (Martin et al. 2020). In the winter, food availability is less diverse. Ptarmigans will forage among willow, birch, or alder stands and consume a limited diet comprised mostly of willow buds, leaves, and twigs (Clarke and Johnson 2005). Despite their dietary restrictions in the winter, mortality due to starvation is exceedingly rare among these birds, and they will successfully adapt to consuming other plant matter if willow is	**0**

		not readily available (Wann et al. 2014).	
2. Predators	Are important predator populations expected to change?	Adult white-tailed ptarmigans are often taken by raptorial birds, including various species of falcon, owls, and eagles, and will be killed by large mammals, such as the coyote, red fox, long-tailed weasel, and occasional mountain lion (Martin et al. 2020). Common nest predators include ravens, mountain lions, foxes, weasels, and ground squirrels, all of which will readily kill either hatchlings or eggs if found (Wiebe and Martin 1997).	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts are known for the white-tailed ptarmigan.	**0**
4. Disease	Is the prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Martin et al. report few known diseases or body parasites in the white-tailed ptarmigan due to their relatively low incidence of parasite infection; some individuals with biting lice, mites, and blood parasites were reported (2020). No information indicates significant negative impact on populations.	**0**
5. Competitors	Are populations of important competing species expected to change?	White-tailed ptarmigan compete with other high-elevation birds for nesting sites and territory, including rock ptarmigans and willow ptarmigans (Martin et al. 2020). Because these species all occupy a similar ecological niche and rely on many of the same resources, it is unlikely that climate change factors will benefit one species but not the others. Brood parasitism is not documented in this species (Martin et al. 2020)	**0**

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