Climate Change Vulnerability Assessment

Four Species in City of Boulder's Open Space and Mountain Parks
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Executive Summary

The City of Boulder's Department of Open Space and Mountain Parks (OSMP) has begun to investigate how new and predicted changes in climate will alter how they approach their mission of preserving and protecting the natural environment and land resources that characterize Boulder. For this work, we have used the NatureServe tool, the Climate Change Vulnerability Index (CCVI), which uses experts' understanding of how species react to changes in temperature and precipitation to make predictions about the species' population size and health, given predicted changes in climate.

We selected four species that vary in their spatial distribution, interactions with other species, and life forms: Big Bluestem, Douglas Fir, Grasshopper Sparrow, and Plains Topminnow. For climate predictions, we use mid-century (2040-2069) projections based on ensemble-averages of sixteen general circulation models and the medium, A1B carbon emissions scenario. Information on these modeling predictions is readily available, but emissions are already exceeding these and higher carbon emissions scenarios. We mapped occurrence records for each species on to maps of predicted changes in climate. These maps were used in conjunction with information gathered from species experts on the biology and ecology of each species, per the published instructions for using the CCVI tool. In addition, we asked experts open-ended questions that could provide a more nuanced narrative understanding of what we know and predict for each species. The CCVI tool produces results where each species' vulnerability falls into one of the following 5 categories:

- **Extremely Vulnerable**: Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050.
- **Highly Vulnerable**: Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.
- **Moderately Vulnerable**: Abundance and/or range extent within geographical area assessed likely to decrease by 2050.
- **Less Vulnerable**: Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will change (increase/decrease) substantially by 2050. Actual range boundaries may change.
- **Insufficient Evidence**: Information entered about a species' vulnerability is inadequate to calculate an Index score.

The results of our study suggest that:

- Douglas Fir and Plains Topminnow are Extremely Vulnerable to the climate changes predicted in Boulder.
- Grasshopper Sparrow is Moderately Vulnerable to these predicted changes, and
- Big Bluestem has a nearly equal chance of falling into any of the three following categories: Extremely Vulnerable, Highly Vulnerable, Less Vulnerable.

The biological/ecological factor most often ranked by our experts as increasing the vulnerability of these four species is their "physiological hydrologic niche". The second most critical factor was "dependence on a disturbance regime likely to be impacted by climate change." Several biological/ecological factors have quite a bit of uncertainty around them, across all species. These include, all measures of genetic diversity, “impact of land use changes resulting from human responses to climate change,” whether or how phenology/seasonality may be changing, the roles of pathogens, natural enemies and competition, the ways disturbance regimes may change, the role of the physiological thermal niche of the plant species, and the role of soils for the plant species.

This report clarifies climate change-related vulnerabilities of four species found on OSMP properties. It also clarifies areas where more work on these topics would benefit managers charged with their care. Expanding the list of species analyzed, investigating biological/ecological factors about which we have little information across species, and working with local partner land management organizations, including Boulder County, to expand the geographic scope of this work would all help to clarify how managers can best support and protect species going forward.

Introduction

The City of Boulder Department of Open Space and Mountain Parks (OSMP) is charged with preserving and protecting the natural environment and land resources that characterize Boulder. More than 45,000 acres of open spaces containing many natural communities, home to hundreds of species are in the department’s care. The City of Boulder has been protecting open spaces for over a century. As the City moves through its second century of protecting open lands, it will face on-going challenges associated with protecting the natural environment and land resources in the context of developing lands and a growing human population. This second century also brings unprecedented management challenges, with the climate itself altering how natural systems function and how species relate to their environment.

The OSMP has begun to investigate how these new and predicted changes in climate will alter how they approach their mission of preserving and protecting of the natural environment and land resources that characterize Boulder. This sort of planning challenge has been taken up by land managers across the country. Managers have found several tools and methods to be helpful in putting bounds on the question of how to manage species and natural communities as they adjust to changes in climate. The first step in planning for management in a climate change future is to try to understand how natural communities or species will react to predicted climate changes. Managers can choose to undertake this vulnerability assessment effort on the scale of a natural community or a species. For either scale, there are climate envelope or niche models that can make predictions about where a species or community will be able to exist in the future given where their optimal climate envelope of temperature and precipitation will move to. In addition, there are models that make non-spatial predictions about population health based on the sensitivity of a species or community to changes in temperature and precipitation.

This report details how four species may react to predicted changes in climate. These predictions are about population health and are based on our understanding of how sensitive each species may be to predicted changes in temperature and precipitation. We use methods developed by the conservation non-profit, NatureServe, called the Climate Change Vulnerability Index (CCVI). Based on the results of this work, OSMP may be able to create tangible management practices to support the continued protection of these species. Moving forward, the predictions outlined in this report may highlight information gaps that OSMP will be able to fill. In addition, OSMP may choose to expand this investigation in terms of the number of species or natural communities, or in terms of space, working in conjunction with regional partners in land management.

Methods

Species Selection

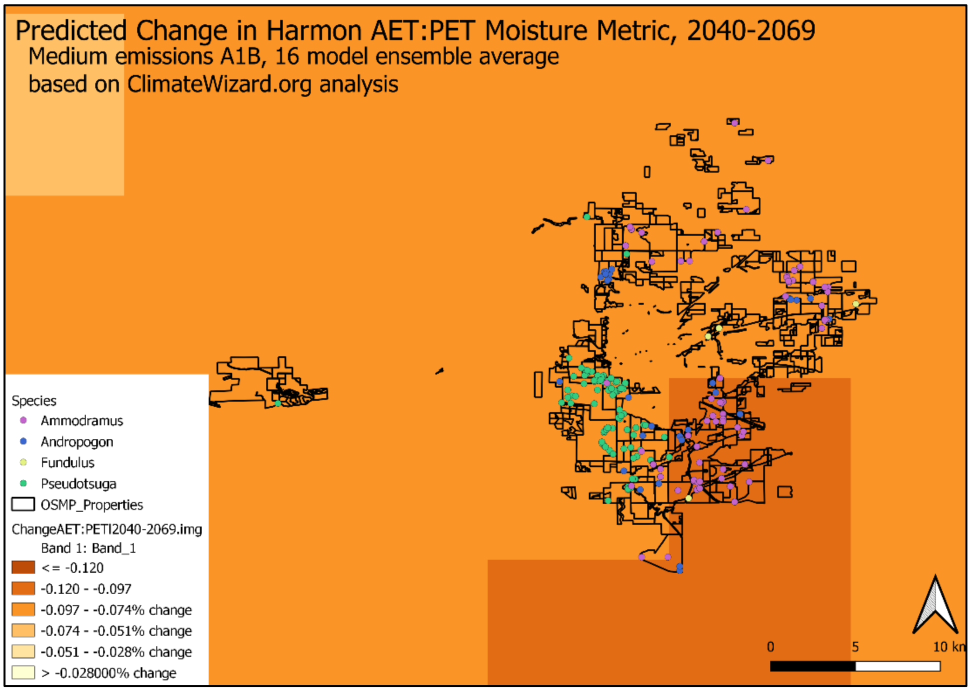
Our aim for this project was to look at a range of species found in the City of Boulder's Open Space and Mountain Parks properties. We chose one common tree species (Douglas Fir) where OSMP properties are the eastern edge of the species range, one geographically widespread but patchy perennial grass (Big Bluestem) where OSMP properties represent the western edge of the range, one common migratory bird (Grasshopper Sparrow) that is a habitat specialist but a generalist eating a variety seeds and insects, and one rare fish species (Plains Topminnow) that is dependent on specific hydrological conditions. We hope that this group of species, spanning life forms, growth habits, abundance and rarity, and habitat requirements may shed some preliminary light on areas in OSMP that warrant a deeper investigation, with respect to climate change vulnerability. At the same time, this project allowed OSMP staff to increase their understanding of how the vulnerability assessment process works, and, given the perceived strengths and weaknesses of the process and results, decide if it is cost effective to extend the analysis to more species.

Species' Climate Change Vulnerability Assessment Tool

We used NatureServe's Climate Change Vulnerability Index tool to assess the vulnerability of four species found in the City of Boulder's Open Space and Mountain Parks properties. This tool is easy for land managers and species experts to use after a short training session, and the results can shed light on priorities for further investigation, environmental factors that may increase the vulnerability of many species and highlight species which may be particularly vulnerable to predicted changes in climate. The tool ranks the climate change vulnerability of species based on their exposure and sensitivity to predicted changes in climate using information on the species' distributions, biologies and ecologies. The tool is intended for use in land management geographies spanning scales from a national park or wildlife refuge to a state; the size of the City of Boulder's OSMP properties falls squarely on the small end of this scale. Please see the document, *Guidelines for Using the NatureServe Climate Change Vulnerability Index, 3.02* for a fuller explanation of the CCVI methods (Young et al., 2016).

Determining Exposure to Predicted Changes in Climate

We used mid-century (2040-2069) climate projections based on ensemble-averages of sixteen general circulation models and the medium, A1B carbon emissions scenario. Carbon emissions are already exceeding this, and all other higher carbon emissions scenarios imagined by the IPCC. However, we used the A1B scenario for this assessment because that is the downscaled model most easily accessible to use with the NatureServe CCVI. Given the scale of the OSMP properties, there was very little variation in climate predictions across the geography of the assessment area.



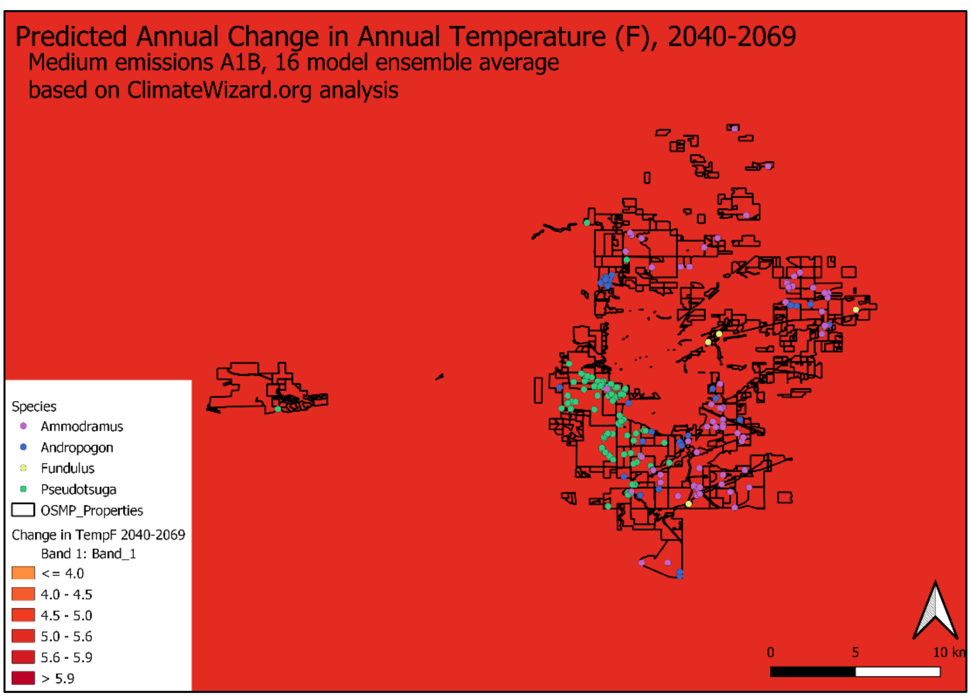


Figure 1: Maps showing mid-century temperature and moisture changes predicted by ensemble-averages of general circulation models using the medium A1B carbon emissions scenario.

We collected records of the occurrences of our four species within the City of Boulder OSMP properties using the online database, GBIF. We overlapped these range maps with maps of predicted changes in temperature and predicted changes in moisture (Fig. 1) and followed NatureServe's methods (Young et al., 2016) determining the changes in temperature and precipitation each species is predicted to experience over its range on OSMP properties.

In order to answer the questions that the CCVI tool poses regarding species' natural history and biology, we interviewed one or two experts for each species. In addition, our experts answered questions as to the species sensitivity (Section C) and natural and anthropogenic migratory barriers (Factors B3a, B3b). All experts consulted were familiar with the species for which they contributed on the City of Boulder's OSMP properties. Experts were all given the same training on answering the assigned questions and most chose to answer the questions during the training session. Some experts read through the questions with the trainer (J. Baty) and answered the questions on their own time. Experts were encouraged to ask and discuss questions during the training and at any point following. Each question/ factor included a section for experts' comments so that they could clarify answers, include citations or specify caveats. At the end of the CCVI-based question session, experts were encouraged to answer two additional non-CCVI questions that were open-ended with regards to climate predictions. Questions were based on Hameed et al., 2013.

1. *This species may be sensitive to what climate changes? Consider all possible changes related to temperature, wind, and precipitation, averages and extremes. For each climate condition, please explain why and in what ways the species is sensitive and how the species might respond.*
2. *Are there biotic or abiotic interactions that may make this species more or less sensitive to climate changes? Explain how each interaction may affect the species' sensitivity to climate changes.*

We used comment box comments and answers to the two additional questions to populate the species descriptions accompanying the CCVI results in this report. This text will help to enrich and clarify the CCVI results to the readers of this report.

Compiling Results

In the winter and spring of 2021, four species experts on staff of the City of Boulder Department of Open Space and Mountain Parks answered questions regarding one of our four species. Each of those experts recommended an external expert who could also speak to the biology and ecology of the species on OSMP properties. All but one of those external experts responded to our questions as well, yielding a total of one to two experts responding to each species. Each set of responses was entered separately, as an individual case, into the NatureServe CCVI tool. One of the outputs of the tool is a distribution of frequencies for results falling into each of the 5 Index scores. This output is generated using a statistical simulation with 1,000 iterations (see Young et al., 2016 for more detail). The frequency distribution for results for each expert's assessment of a given species were averaged, and these scores are reported here. This method allowed for weighting of the experts' responses. For example, if both experts answered the question with overlapping uncertainty, this method weights the overlap more heavily.

The five CCVI results categories and their definitions are as follows:

Extremely Vulnerable: Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050.
Highly Vulnerable: Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.
Moderately Vulnerable: Abundance and/or range extent within geographical area assessed likely to decrease by 2050.
Less Vulnerable: Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will change (increase/decrease) substantially by 2050. Actual range boundaries may change.
Insufficient Evidence: Information entered about a species' vulnerability is inadequate to calculate an Index score.

Results

Of the four species assessed for this report, two, Douglas Fir and Plains Topminnow, are predicted to be Extremely Vulnerable to predicted changes in climate in the City of Boulder's Open Space and Mountain Parks. One species, the Grasshopper Sparrow, is predicted to be Moderately Vulnerable to predicted changes in climate in OSMP. One species, Big Bluestem, has a nearly equal chance of falling any of the following categories: Extremely Vulnerable, Highly Vulnerable, or Less Vulnerable.

Of the twenty-three factors contributing to a species' vulnerability to predicted climate changes that were assessed as part of this report, Physiological Hydrologic niche was the most critical factor: the one most often ranked to Greatly Increase or Increase vulnerability of our four species, with all four species ranked into those categories (Big Bluestem and Grasshopper Sparrow had some uncertainty around this factor).

The second most critical factor was "dependence on a disturbance regime likely to be impacted by climate change," with all four species being ranked as Increase, Somewhat Increase, or Neutral. Big Bluestem and Douglas Fir had some uncertainty around this factor.

Several factors rose to the top of uncertainty in this study. We know little about the genetics of any of these species within the OSMP or even within the species across its entire range. In addition, we know little about the "Impact of land use changes resulting from human responses to climate change" for any of these species. Other factors with uncertainty across more than one species include: Whether and how phenology may be changing, the roles of pathogens, natural enemies and competition, the ways disturbances regimes may change and influence these species, the role of the physiological thermal niche of the plants, and the role of soils for the plants.

Table 1: Importance of CCVI factors across all species
B: Big Bluestem, D: Douglas Fir, G: Grasshopper Sparrow, P: Plains Topminnow

	Greatly increase	Increase	Somewhat increase	Neutral	Unknown
Exposure to sea level rise				BDGP	
Distribution relative to natural barriers		P		BDG	
Distribution relative to anthropogenic barriers	P		B	BDG	
Impact of land use changes resulting from human responses to climate change					BDGP
Dispersal and movements	B		BDP	G	
Historical thermal niche				BDGP	
Physiological thermal niche	D		GP	BDG	
Historical hydrological niche				BDGP	
Physiological hydrological niche	DP	BDG		BG	
Disturbance regime		DP	BG	BD	
Ice, ice-edge or snow-covered habitats			D	BDGP	
Uncommon landscape or geological features			BD	BDGP	
Other species to generate habitat			D	BDPG	
Dietary versatility				GP	BD
Pollinator versatility				BD	GP
Other species for dispersal				BDGP	
Pathogens or natural enemies	D		DGP	BG	
Competition			BDP	BG	
Other interspecific interaction				BDGP	
Measured genetic variation				D	BGP
Genetic bottlenecks					BDP
Reproductive system			B	B	DGP
Phenological response				DG	BP

Results for individual species follow.

Big Bluestem, *Andropogon gerardii*

Perennial grass

Contributing experts: Lynn Riedel, David Buckner

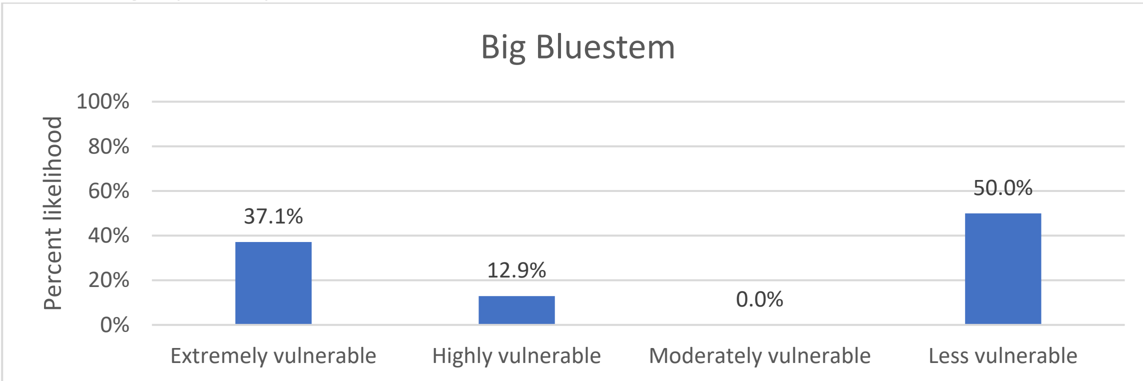


Figure 2: Big Bluestem is categorized as Less Vulnerable to predicted climate changes, although there is very high uncertainty around this result.

	Greatly increase	Increase	Somewhat increase	Neutral	Unknown
Exposure to sea level rise				X	
Distribution relative to natural barriers				X	
Distribution relative to anthropogenic barriers			X	X	
Impact of land use changes resulting from human responses to climate change					X
Dispersal and movements			X	X	
Historical thermal niche				X	
Physiological thermal niche				X	
Historical hydrological niche				X	
Physiological hydrological niche		X		X	
Disturbance regime			X	X	
Ice, ice-edge or snow-covered habitats				X	
Uncommon landscape or geological features			X	X	
Other species to generate habitat				X	
Dietary versatility					NA
Pollinator versatility				X	
Other species for dispersal				X	
Pathogens or natural enemies				X	
Competition			X	X	
Other interspecific interaction				X	
Measured genetic variation					X
Genetic bottlenecks					X
Reproductive system			X	X	
Phenological response					X

Table 2: Big Bluestem may be more vulnerable to predicted climate changes due to its physiological water needs.

Little is known about the genetic diversity of this plant in Boulder's OSMP or about the plant's ability to track changing seasonality.

Insights from Experts:

General

Big Bluestem occupies areas based on habitat requirements, which results in a very patchy distribution. On the other hand, this species is found across North America and is a very old species, so it may be very resilient to different climatic conditions.

Climate conditions & phenology

Long-term studies of this species on surfaces stable throughout the entire Pleistocene suggest that Big Bluestem is highly resistant to being displaced by climatic changes. On OSMP properties, some of the sites where the plant is found are above currently wetted stream alluvium that is probably substantially supported by moisture stored in pedogenic clay horizons. As such, it is buffered from year-to-year changes in precipitation.

Because Big Bluestem is deep-rooted, rhizomatous and long-lived, it can weather periods of drought and lower recruitment opportunity fairly well, even in the semi-arid climate of the Front Range. However, we don't know how long this species can tolerate periods of lower precipitation and warmer temperatures. Prolonged decreases in the amount of summer precipitation could cause a decline in this and other warm-season species. Big Bluestem and associated warm-season species are adapted to late summer monsoon rains.

Pulses of unusually high amounts of precipitation during non-summer months could help provide recharge of moisture that is held at depth (approximately 50 cm) in local soil profiles where Big Bluestem is prevalent- especially in areas with older soils on outwash mesas. However, extra precipitation during fall, winter, or spring over the long-term could favor competitive cool season vegetation.

Dispersal, movement & genetics

Big Bluestem populations in the Colorado Front Range show very distinct dissimilarity to the plains and Midwestern prairie populations. These populations are disjunct, at the western edge of their range, and reduced in extent due to human development. Their patchy distribution is due to the patchiness of areas with necessary habitat requirements.

Big Bluestem presence and abundance is primarily supported in the long-term by vegetative propagation via rhizomes. Supported by vegetative parts, this species appears to have very high tenacity to sustain itself through long-term climate variation. Its seed viability rates are erratic in the OSMP area. If viable seeds were produced, they would have a good chance to disperse fairly widely due to the very windy conditions often present. Urban and agricultural development would be barriers to movement to the east and south.

Populations of Big Bluestem in the Front Range are probably about ¼ hexaploid and about ¾ nonaploid. It has been speculated that this high proportion of nonaploidy is reflective of the species' response to highly variable climate conditions. In other words, the prevalence of polyploidy in Big Bluestem in this area may be a response to past climate “challenges” and suggest that it is well-positioned to react similarly to any new challenges.

Abiotic conditions: disturbance, soils, geology

Big Bluestem is dependent on fire and grazing. There is uncertainty about how changes in these managed disturbances due to climate change would affect Big Bluestem and associated tallgrass communities on OSMP properties. Increased temperature and precipitation could lead to reduced ability to conduct prescribed burns. However, wildfire could increase fire frequency and fire intensity. Grazing by cattle and prairie dogs is also a natural or mimicked natural disturbance that is monitored and managed on OSMP to benefit tallgrass prairies. Warmer and drier conditions could cause OSMP to change the management of this manipulated disturbance regime.

The primary sites where Big Bluestem occurs in the OSMP area are geologically very stable and are not prone to disturbances like flooding and erosion. Experts do not foresee this changing with changes in climate.

Biotic interactions

Big Bluestem has demonstrated strong resistance to being displaced by other native or non-native species. However, competition from cool season non-native grasses and forbs could increase and displace Big Bluestem over time if most precipitation comes during fall, winter, and spring.

In addition, increased atmospheric nitrogen deposition may cause increased competition from nitrogen-loving plant species (many non-natives). Local soils in tallgrass habitat are naturally low in nutrients and native ecotypes are adapted to those conditions. Higher cool season precipitation combined with nitrification could create a strong competitive advantage for cool season non-native plant species.

Bibliography and contacts

- McAllister and Miller. 2016. Single nucleotide polymorphism discovery via genotyping by sequencing to assess population genetic structure and recurrent polyploidization in *Andropogon gerardii*. American Journal of Botany. 103:1314
- Tamang, T. M. 2016. Determination of Evolutionary History of Big Bluestem Populations Through Chloroplast DNA Analysis. MS Theses. Fort Hays State University.

Douglas Fir, *Pseudotsuga menzeisii*

Coniferous tree
Contributing experts: Thomas Veblen, Chris Wanner

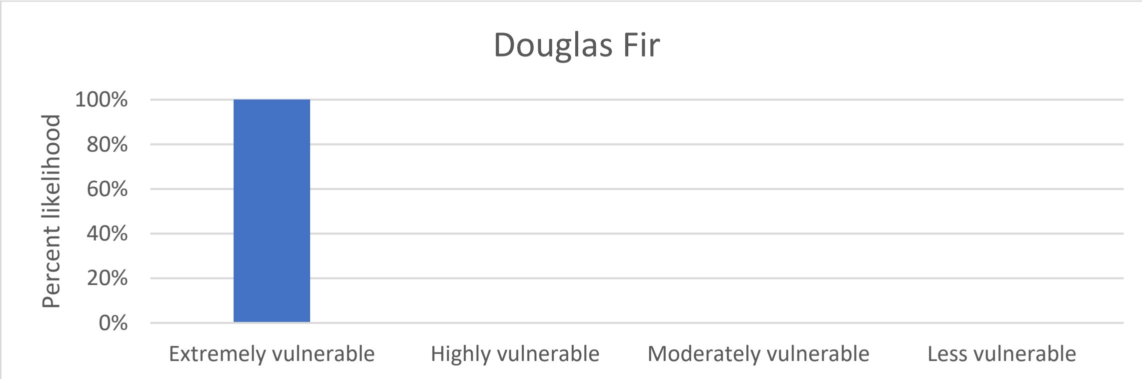


Figure 3: Douglas Fir is categorized as Extremely Vulnerable to predicted climate changes.

	Greatly increase	Increase	Somewha t increase	Neutral	Unknown
Exposure to sea level rise				X	
Distribution relative to natural barriers				X	
Distribution relative to anthropogenic barriers				X	
Impact of land use changes resulting from human responses to climate change					X
Dispersal and movements			X		
Historical thermal niche				X	
Physiological thermal niche	X			X	
Historical hydrological niche				X	
Physiological hydrological niche	X	X			
Disturbance regime		X		X	
Ice, ice-edge or snow-covered habitats			X	X	
Uncommon landscape or geological features			X	X	
Other species to generate habitat			X	X	
Dietary versatility					NA
Pollinator versatility				X	
Other species for dispersal				X	
Pathogens or natural enemies	X		X		
Competition		X			
Other interspecific interaction				X	
Measured genetic variation				X	
Genetic bottlenecks					X
Reproductive system					X
Phenological response				X	

Table 3: Douglas Fir may be more vulnerable to predicted climate changes due to its thermal and hydrologic niches and its dependence on disturbance for reproduction. Seedlings may not compete against herbaceous vegetation. This species is vulnerable to pathogens and herbivores.

Insights from Experts:

General

Refugia will become very important in maintaining populations of Douglas Fir on OSMP properties. Everything we know about drying and climate predictions indicates that natural regeneration of Douglas Fir in the Front Range will not be feasible outside of riparian areas. What may happen is that severe fires and insect herbivores like bark beetles and budworm will kill trees and remove seed sources. Afterwards, managers will have to decide whether it is worth reforesting with Douglas Fir and where to do it. In the 1980's, following outbreaks on Boulder County open space and USFS land, regeneration of Douglas Fir was fine. Based on that information, in the climate of 40 to 50 years ago, many managers believe low-elevation regeneration of Douglas Fir will not be a problem. All current evidence suggests this is simply not true anymore. In a fire-management or fire-fighting scenario, preservation of Douglas Fir trees in riparian areas needs to be prioritized.

Pinyon Pine, Juniper, and perhaps Limber Pine will survive warmer and drier conditions and are common further south. The USFS is already thinking about assisted migration with their adaptive silviculture experiments in the region.

Climate conditions & phenology

Modelling studies based on climate envelopes show moisture availability will completely prevent Douglas Fire regeneration at low elevations. As to the survival of mature trees, there is a lot of uncertainty. So far, we have not seen direct climate-cause tree mortality of Douglas Fir the way we have with higher elevation conifers. However, we have seen an increase in conifer mortality at all elevations across the west, and that is predicted to continue. There could be riparian areas on OSMP properties where Douglas Fir could survive for a long time. In general, under warmer conditions, we would expect the range of the species to move upslope.

In addition to temperature, we know that the indirect impact of snow and snowmelt is important to Douglas Fir. January snow cover is a good predictor of locations where Douglas Fir can regenerate. Earlier snowmelt and a reduction in snow will be a problem for the survival of seedlings.

Phenology tracking changes in climatic seasonality might only be important at high elevations if dormancy were to break too early. Phenology mismatches may not be an issue at the low elevation OSMP properties.

Dispersal, movement & genetics

Douglas Fir has a very wide range with good genetic diversity. The tree is wind pollinated. There is no indication that it has gone through any population bottlenecks that would decrease its genetic diversity.

Forest management studies interested in adequate stocking show that the tree disperses 200 feet, on average. From a species preservation perspective, less common, more distant dispersal events may be important too. Most of the tree's dispersal is by gravity but there is also some dispersal by small animals, including mice, squirrels, and Clark's nutcracker.

Abiotic conditions: disturbance, soils, geology

On OSMP properties, riparian forests are very important for Douglas Fir, especially in areas like Gregory Canyon. Protecting riparian habitats will be critical to the protection of this species in the OSMP. In addition to providing the moisture the tree needs, the tree's dispersal primarily happens in riparian corridors. Our management has been aimed at reducing the number of trees because traditional thinking has been about fuels reduction and fire management. Managers will need to get out of the old mindset of, "fewer trees equals less fuel," because we are already seeing that Douglas Fir trees are not coming back after fire in this area.

In terms of fire, mature Douglas Fir trees are not dependent on it, neither is regeneration. However, there are other taxa in the Douglas Fir communities that are dependent on fire. High severity fire can create good opportunities for regeneration, but the seedlings will not survive under the drier conditions predicted for the future. Likewise, floods that scour are good for regeneration, unless managers plant grasses to stabilize the scoured sites. If a seed source is present and the site is not permanently waterlogged, flooding could be a benefit for Douglas Fir on OSMP properties.

Biotic interactions

Biotic interactions are important for this species. While most of the dispersal of Douglas Fir's seeds is done by gravity, especially in riparian corridors, there is also some dispersal by small animals, including mice, squirrels, and Clark's nutcracker. In addition, competition with other plants is important; where there is more grass cover, there is less opportunity for Douglas Fir to establish.

Some of the most important biotic interactions for the survival of this species into the future revolve around natural enemies. The most important insect herbivores on Douglas Fir in this area are the bark beetle, *Dendrocotonus pseudostugae*. Under warmer conditions, the bark beetle has more frequent outbreaks and is 100% lethal. More and more outbreaks of the bark beetle are happening in the Front Range. These result not only in direct mortality, but also in the loss of seed sources. In addition to the bark beetle, Western Spruce Budworm, a defoliator, is very common. On OSMP properties, Douglas Fir is the tree that is attacked most frequently by the budworm. Mortality due to this insect is highly variable and sometimes the trees recover. The third insect herbivore that is important to Douglas Fir is the Tussock Moth. This insect may not currently be found in OSMP, but it is likely to appear under warmer, drier climate conditions. In terms of natural enemies, the only saving grace for Douglas Fir in OSMP is that it exists in small patches, rather than large pure stands, and an outbreak elsewhere would have a harder time spreading to these small, isolated patches.

Bibliography and contacts

For consideration of community-level changes on a regional scale, please refer to a report by USFS Jeannine Rice- based on a questionnaire approach- a back and forth with about 10 Southern Rocky region community-type experts. This recommendation comes from Tom Veblen.

Grasshopper Sparrow, *Ammodramus savannarum*

Migratory songbird
Contributing experts: Carl Bock, Heather Swanson

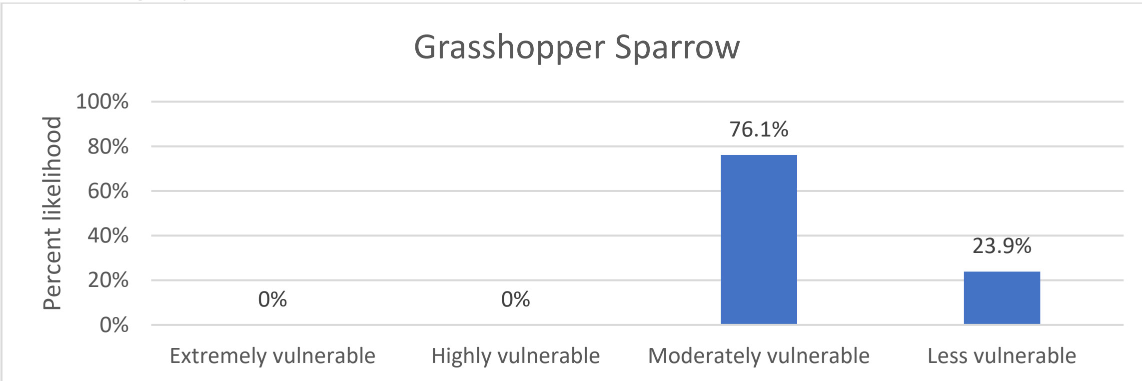


Figure 4: Grasshopper Sparrow is categorized as Moderately Vulnerable to predicted climate changes, with a chance of being Less Vulnerable.

	Greatly increase	Increase	Somewhat increase	Neutral	Unknown
Exposure to sea level rise				X	
Distribution relative to natural barriers				X	
Distribution relative to anthropogenic barriers				X	
Impact of land use changes resulting from human responses to climate change					X
Dispersal and movements				X	
Historical thermal niche				X	
Physiological thermal niche			X	X	
Historical hydrological niche				X	
Physiological hydrological niche		X		X	
Disturbance regime			X		
Ice, ice-edge or snow-covered habitats				X	
Uncommon landscape or geological features				X	
Other species to generate habitat				X	
Dietary versatility				X	
Pollinator versatility					NA
Other species for dispersal				X	
Pathogens or natural enemies			X	X	
Competition				X	
Other interspecific interaction				X	
Measured genetic variation					X
Genetic bottlenecks					X
Reproductive system					X
Phenological response				X	

Table 4: The Grasshopper Sparrow may be more vulnerable to predicted climate changes due to its physiological hydrologic niche.

Little is known about the genetics of this species in Boulder OSMP.

Insights from Experts:

General

Grasshopper Sparrow requires a substantial amount of mid- to tall-grass cover in its habitat. On OSMP properties, it avoids suburban edges. In large areas of agricultural or urban development, there is a direct loss of habitat, and a loss of good-quality habitat due to edge effects. Grasshopper Sparrow would never be found in areas with low cover, such as on a prairie dog town.

Climate conditions & phenology

Many birds in North America are changing the seasonality of their migrations, but our experts could not speak to whether Grasshopper Sparrows are. One of the reasons grassland birds migrate is to avoid snow.

If changes in climate cause shifts in tallgrass prairie distribution in OSMP it may impact the distribution of Grasshopper Sparrows too.

In southern Arizona, Grasshopper Sparrow is very sensitive to high ground temperatures and seeks refuge in shady places in the summer.

Dispersal, movement & genetics

Grasshopper Sparrows' young do not come back to the same area where they were reared, so as a species, it should be able to continue to track appropriate habitats. The species has site fidelity with breeding and outside the breeding season.

Abiotic conditions: disturbance, soils, geology

Fire is important in the habitat of the Grasshopper Sparrow. With predicted changes in climate, managers may have less ability to use prescribed fire, but increased incidence of wildfire could benefit the species. In addition, a climate-induced increase of prairie dogs could increase the vulnerability of Grasshopper Sparrows.

In the short-term, the effects of fire on Grasshopper Sparrows are strongly negative because fire reduces the cover of grass. On the other hand, fire is important for grassland because it prevents the invasion of shrubland or trees. Grasslands may take 2-3 years until the flush cover the birds need has returned. Increased fire frequency could, therefore, be very negative.

Grazing can likewise be negative for the Grasshopper Sparrow, in that it reduces the cover of grass. In a hotter, drier future, the impacts of grazing would be even more detrimental.

Biotic interactions

Grass height, rather than species, is very important to Grasshopper Sparrows. In southern Arizona, the Grasshopper species has been found to be very sensitive to high temperatures and seeks refuge in shady places in the summer. Moreover, the major determinant of nesting success in this species is predation. Vegetation provides cover for eggs and nestlings from predators like snakes, mammals, predatory birds, and probably suburban cats.

Grasshopper Sparrows are generalists and eat all sorts of insects in the summer. In the winter they eat all sorts of seeds.

Bibliography and contacts

Will Keeley

Janet Ruth who worked with USGS in Arizona

Plains Topminnow, *Fundulus sciadicus*

Freshwater Topminnow
Contributing expert: Don D'Amico

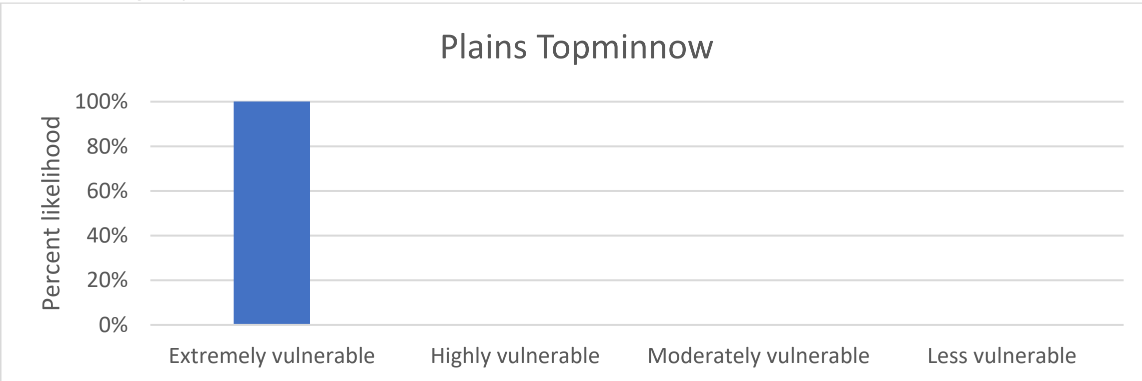


Figure 5: Plains Topminnow is categorized as being Extremely Vulnerable to predicted climate changes.

	Greatly increase	Increase	Somewhat increase	Neutral	Unknown
Exposure to sea level rise				X	
Distribution relative to natural barriers		X			
Distribution relative to anthropogenic barriers	X				
Impact of land use changes resulting from human responses to climate change					X
Dispersal and movements			X		
Historical thermal niche				X	
Physiological thermal niche			X		
Historical hydrological niche				X	
Physiological hydrological niche	X				
Disturbance regime		X			
Ice, ice-edge or snow-covered habitats				X	
Uncommon landscape or geological features				X	
Other species to generate habitat				X	
Dietary versatility				X	
Pollinator versatility					NA
Other species for dispersal				X	
Pathogens or natural enemies			X		
Competition			X		
Other interspecific interaction				X	
Measured genetic variation					X
Genetic bottlenecks					X
Reproductive system					X
Phenological response					X

Table 5: The Plains Topminnow may be more vulnerable to predicted climate changes due to its inability to cross natural and anthropogenic barriers, due to its dependence on a specific hydrology, and due to its dependence on disturbance.

Little is known about the genetics or the seasonality of this species.

Insights from Experts:

Dispersal, movement & genetics

Barriers to movement in streams on OSMP properties, including water diversion structures, culverts, and drop structures, create challenges to movement within and between potential habitats.

Biotic interactions

Western mosquitofish could cause reductions in Plains Topminnow populations.

Bibliography and contacts

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Conclusions and Next Steps

This report clarifies climate change-related vulnerabilities of four species found on OSMP properties. It also clarifies areas where more work on these topics would benefit managers charged with their care. Expanding the list of species analyzed, investigating biological/ecological factors about which we have little information across species, and working with local partner land management organizations, including Boulder County, to expand the geographic scope of this work would all help to clarify how managers can best support and protect species going forward.

The four species assessed for this report include plants and vertebrates, and represent a diverse array of life history strategies, habitat preferences and rareness. One widespread, common tree and one rare, hydrologic regime-dependent fish were predicted to be Extremely Vulnerable to predicted climate changes. What these species have in common is their dependence on water for regeneration or survival. A third species, Big Bluestem, which had large uncertainty regarding its vulnerability category is a warm season, grass that generally does well under drought conditions, at the edge of its continental range in OSMP, but the extent to which it can tolerate drought is largely unknown. Indeed, of the twenty-three factors contributing to a species' vulnerability to predicted climate changes, Physiological Hydrologic niche was the one most often ranked to Greatly Increase or Increase vulnerability of our four species. Based on this information, it is likely that an investigation of species within OSMP that are dependent on a specific moisture regime or reside in habitats or natural communities dependent on a specific moisture regime will uncover themes or patterns that OSMP staff may be able to use to form broad management strategies.

The one species which was predicted to be only Moderately Vulnerable to predicted changes in climate in OSMP is sensitive to high temperatures and dependent on a specific habitat structure but is very mobile and not dependent on any one other species for its survival. In any expansion of this research topic, we recommend OSMP includes migratory species for which habitat integrity or interspecific interactions are important on a variety of scales. This information may allow managers to find patterns that would help them protect migratory species as the landscape changes in response to climate.

The Plains Topminnow is dependent on specific water levels in the streams in Boulder OSMP. While the climate of Boulder is predicted to get drier overall in the coming decades, it is difficult to predict how the impact of a warming, drying climate and increased development and demand for water for human uses will combine for the survival of this species. The City of Boulder will need to continue to partner with water management organizations and other local land management organizations to ensure this fish has that habitat conditions it and other riparian or aquatic species need to survive.

This study also begins to highlight some of the areas where OSMP staff may choose to direct future research and monitoring efforts. Little is known about the genetic diversity of populations of any of the four species within the OSMP. Low genetic diversity can contribute to less resiliency with regards to a changing climate. Understanding the genetic diversity of the species on OSMP properties will help the City to fully understand how to prioritize their conservation under changing conditions.

Similarly, OSMP may consider directing efforts at understanding species phenological responses to changes in climate. Citizen Science-driven efforts at understanding phenology at a continental scale maybe an easy way for OSMP to tap into and participate in phenology data collection. Project Budburst and the Cornell Lab of Ornithology have large, well-regarded phenology-oriented citizen science programs; participation could help with OSMP's mission to foster appreciation and use of OSMP properties that sustain the natural values of the land for current and future generations.

In addition, we know little about the role of pathogens, natural enemies and competition, and the ways disturbance regimes may change and influence these species. With most species occurring on highly managed lands, the roles of disturbance regimes are complex and have interactions with which managers have quite a bit of control over.

Most of the species managed by OSMP have local ranges that extend beyond actual OSMP properties. While understanding what each species is doing on OSMP properties is of immediate use to OSMP managers, understanding how those species and their populations are interacting with the landscape on a larger scale will ultimately lead to the best protections for those species.

Lastly, it is important to note that predicting the futures of species or natural communities based on predictions of changes in climate based on predictions of carbon emissions are imprecise, at best. The last recommendation in this report is to monitor species to see where our climate change vulnerability predictions are most and least accurate. This can help to inform adaptive management practices as well as future planning efforts to support species conservation.

Table 6: Areas where OSMP may choose to direct future climate change research efforts

Expand geography	Any land management organization whose properties OSMP species occupy.
Investigate more species	Migratory species, species with specific hydrologic requirements, rare species, iconic species.
Investigate targeted "factors"	Genetic diversity, interspecific interactions (including pathogens), changes to disturbance and land-use (or water-use) driven by climate changes.
Monitoring	Monitor whether the results predicted by this report are manifesting in the field.

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