RECREATION AND WILDLIFE IN WASHINGTON: CONSIDERATIONS FOR CONSERVATION

A REPORT ON CURRENT KNOWLEDGE

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August 2022

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ACKNOWLEDGEMENT

Native peoples in Washington have stewarded this region since time immemorial and we are deeply thankful for their care of this land over many generations. We acknowledge that Tribal Treaty rights are protected under federal law, which include tribal access to off reservation hunting, fishing, and gathering. Tribal concerns about recreation in Washington elevate the need to better understand the impacts that recreation has on natural, cultural, and tribal resources. As recreation continues throughout the state, tribal rights and interests on public lands must be respected and considered in recreation management and planning.

EXECUTIVE SUMMARY

Outdoor recreation opportunities and participation have grown markedly in recent decades and the effects of recreation on wildlife behavior, fitness, and populations is a growing conservation concern. Numerous literature reviews of outdoor recreation effects on wildlife have been produced in recent years, with the rapidly growing body of scientific literature demonstrating that recreation may affect wildlife at the individual, population, and community level. Recreation can impact wildlife in myriad ways and varies depending on the interaction of numerous variables, including wildlife species, habitat type, and recreational activity. As a result, targeted, local scientific review of wildlife-recreation research is needed to mitigate potential negative effects of recreation on wildlife and encourage coexistence. This is particularly important for the western United States, which holds both the largest percentage of public lands and protected wildlife habitat, and is experiencing some of the highest population growth rates.

Washington State has the second largest population in the West (7.7 million people and growing), and its primary metropolis, Seattle, has consistently been one of the fastest growing cities in the country. Washington holds myriad unique ecoregions, diverse wildlife communities, and remarkable opportunities for recreation; features that highlight the importance of a holistic understanding of the connections between wildlife and recreation. This report aims to provide a species-specific synthesis of recreation impacts for animals in Washington that are of interest to Conservation Northwest and reveal how animals may be responding to locally important types of recreation. The scope of this report is focused on the effects of year-round, terrestrial motorized and non-motorized recreational activities on terrestrial mammal and bird species. For each species we have summarized the relevant body of literature on specific recreation impacts and conclude with a discussion of both areas for future research and special recreation coexistence considerations in Washington. We aim to collate Washington-specific knowledge gaps to aid conservation practitioners in identifying and protecting habitat that supports robust wildlife populations, while still accommodating outdoor recreation activities.

The majority of the literature identified for review in this report documented short-term behavioral changes and patterns of spatial and temporal displacement of wildlife in response to recreational disturbance. Wildlife responses to recreation were abundantly negative, yet few studies relate these responses to the species fitness, abundance, or distribution of wildlife populations. Our findings support the broad scale wildlife-recreation trends and patterns that have been discussed in other reviews, and we identified key areas where conservation practitioners in Washington can focus management and policy efforts. These include identifying the extent of wildlife-recreation overlap, measuring the thresholds at which varying levels of recreation intensity affect wildlife populations, protecting critical spatial and temporal refugia from recreation, and implementing management actions to mitigate recreation impacts. Across these key areas we highlight the following areas of focus:

- Identifying wildlife-recreation overlap in Washington
    - Mapping and modeling the extent of Washington's recreation footprint with species ranges to identify overlap and priority areas to focus wildlife-recreation coexistence efforts.
- Measuring recreation intensity and frequency
    - Prioritizing data collection at recreational areas across the state that can be used to quantify timing, frequency, magnitude, predictability, locations, and areas of recreation influence.
    - Pairing recreation intensity levels with species-specific thresholds of tolerance to prioritize and direct management strategies on a fine scale.
- Protecting spatial and temporal refugia
    - Protecting critical habitats that serve as spatial refugia from recreational development. This is especially important for wide-ranging umbrella species that are sensitive to disturbance and have specific habitat requirements.
    - Carefully planning for future recreational development with a focus on concentrating recreation impacts to lower-quality habitats for vulnerable species and consolidating trail networks to limit habitat fragmentation and the spatial footprint of recreation.
    - Encouraging recreationists to consolidate use to developed recreation areas and reduce their overall recreation footprint.
    - Reducing road densities through wildland areas by decommissioning select roads and limiting the construction of new roads.
    - Maintaining temporal refugia for species that can adjust their behavior to avoid peak periods of recreational use, such as nighttime closures of high-use trail networks.
    - Seasonally closing and/or restricting off-road and off-trail use in important reproductive or over-wintering areas to limit disturbance to species of interest during vulnerable seasons and life history phases (e.g., mule deer winter range, wolverine denning habitats).
- Implementing management actions
    - Using information from the literature and mapping efforts as baselines for adaptive management studies.

- Employing adaptive management practices to implement on the ground actions that work towards conservation goals even in situations where limited data is available.

Conservation practitioners need wildlife-recreation information summarized at a local scale to best manage recreation, advocate for effective policy, and protect habitat that supports robust wildlife populations while still accommodating outdoor recreation activities. As human populations continue to grow, wildlife increasingly face human-induced challenges that impact their persistence and survival. This may be especially important for Washington species that are particularly sensitive to disturbance, including threatened and endangered species, such as Canada lynx, grizzly bear, sage-grouse, marbled murrelet, wolverine, bighorn sheep, and mountain caribou. Outdoor recreation impacts are a piece of this larger puzzle, and the recent increases in outdoor recreation participation highlight an urgent and immediate need to both better understand and mitigate recreational impacts on wildlife. The information within this report provides a starting point for practitioners seeking to limit biodiversity loss and encourage wildlife-recreation coexistence into the future.

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INTRODUCTION

Participation in outdoor recreation activities has dramatically increased over recent decades (Outdoor Foundation 2021). In the United States, the number of visitors to National Park Service lands was more than 15 times higher in 2017 (n = 331 million) than in 1946 (n = 22 million; Duffy 2020) and campground reservations on United States Forest Service (USFS) lands increased by 95% between 2008 and 2017 (Shartaj and Suter 2020). Outdoor recreation has both high economic and human health value and is an important link to conservation since it can foster connections to nature, instill pro-environmental behaviors, and encourage broad support for conservation organizations (Larson et al. 2019). Despite these positive attributes, outdoor recreation comes with the inherent effects of concentrated human activity, including degraded landscapes and negative impacts on wildlife populations (Duffy 2020, Larson et al. 2019, Siikamäki 2009, Miller et al. 2020).

Numerous literature reviews of outdoor recreation effects on wildlife have been produced in recent years (e.g., Larson et al. 2016, Larson et al. 2019, Gaines et al. 2003, Miller et al. 2020, Sato et al. 2013, Switalski 2016, Stankowich 2008, Hennings 2017, Green and Higginbottom 2000; see *Suggested Reading*), where the impact of outdoor recreation activities on wildlife varies widely between activity type, geographic location, landscape characteristics, and species-specific behavior. As outdoor recreation increases around the globe, the rapidly growing body of scientific literature shows that recreation can affect wildlife at the individual, population, and community level (Miller et al. 2020, Larson et al. 2016, Larson et al. 2019).

Wildlife responses to recreation occur at nested levels of disturbance and are moderated by context dependent factors (i.e., species-specific sensitivity to recreation, recreation type, recreation intensity, timing and season, habitat and topography, the spatial extent of recreation; Miller et al. 2020). At the most basic level, wildlife may display short-term behavioral shifts or experience temporary physiological changes when disturbed by recreationists. By measuring responses such as increased vigilance, heart rate, or flight distance, these studies can document the sensitivity of a wildlife population to recreation and suggest management activities (e.g., buffer zone distances between recreationists and animals) to reduce animals' responses to recreation. However, these studies are limited in that short-term responses to recreation do not necessarily translate to individual or population-level impacts (Bateman and Fleming 2017). Long-term impacts of recreation to individual animals occur when short-term responses result in lower survival, reproduction, space use changes, or long-term stress (e.g., by reducing foraging opportunities or increasing energetic demands). The increased complexity of measuring longer-term impacts make these studies difficult to conduct and less prevalent; however, results from such research require fewer assumptions when inferring whether recreation is impacting wildlife populations or distribution. Studies that definitively document population or distribution level effects of recreation require the least amount of inference, but documenting these recreational impacts presents the most challenging research to conduct and studies that do so are rare (Miller et al. 2020).

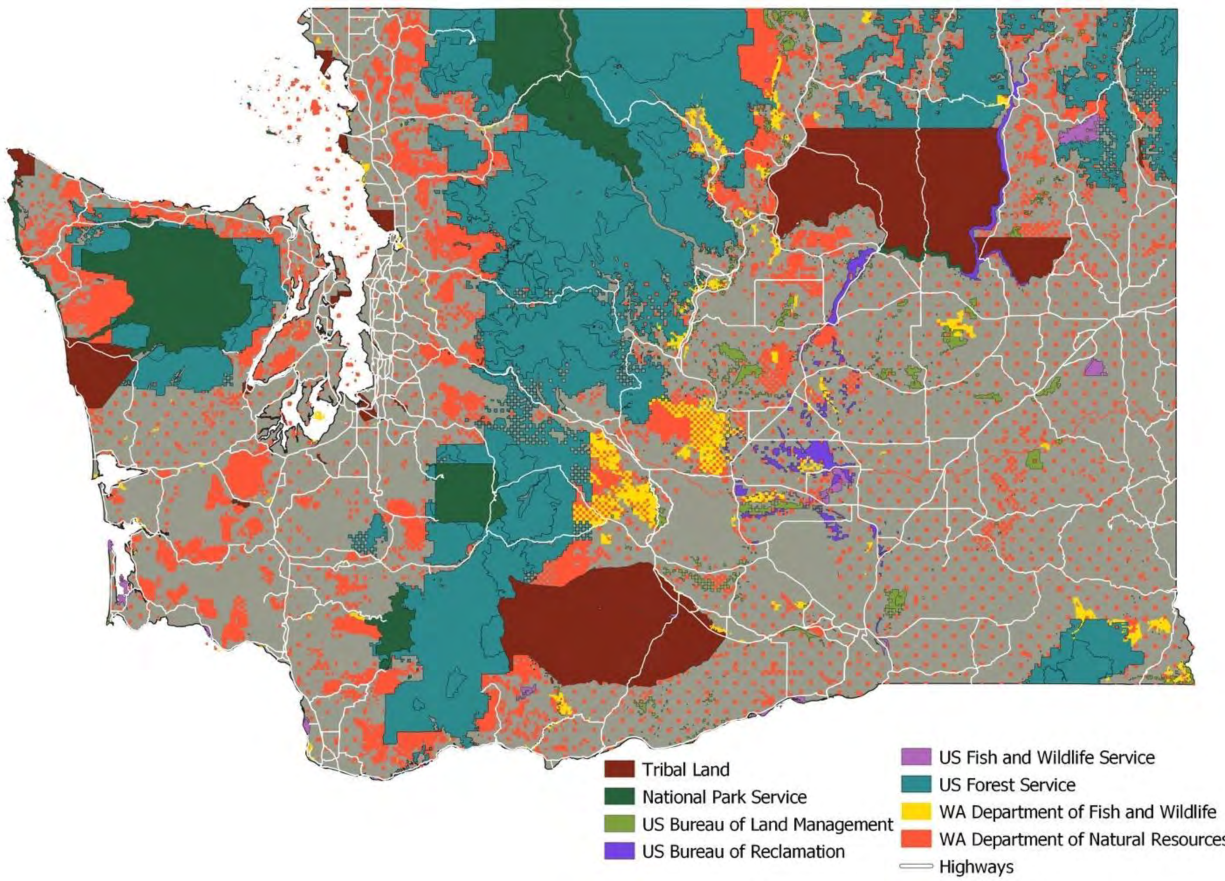
Key factors that influence wildlife responses to recreation include the type, timing, location, frequency, and predictability of outdoor recreation activities (Knight and Cole 1991, Hennings 2017, Miller et al. 2020). In 2020, the USDA published a report of recreation and wildlife on public lands by synthesizing 17 review papers published between 2003 and 2017 (Miller et al. 2020). This comprehensive report outlines four primary wildlife-recreation trends:

- Animals tend to have stronger responses to less predictable forms of recreation.
- Reproductive status is important; pregnant females and young tend to be more vulnerable.
- Season is also important; responses may differ between summer and winter.
- Habitat generalists are less vulnerable than habitat specialists.

In addition to these broad trends highlighted by Miller et al. (2020) we note the following patterns commonly encountered in the wildlife-recreation literature:

- Wildlife species capable of behavioral plasticity may adjust activity temporally to avoid recreation (e.g., diel patterns, seasonal use of recreation areas, avoidance of recreation areas on weekends; Lewis et al. 2021).
- As the intensity of recreation increases, so does the impact to wildlife (Nelson and Bailey 2021).
- Non-motorized recreation is more disturbing to most wildlife than motorized activities. However, motorists can cover more ground, thus increasing the geographic extent of their impact (Stankowich 2008, Larson et al. 2016; but see Larson et al. 2020).

These general trends provide a starting point for understanding wildlife-recreation dynamics; however, conservation practitioners need wildlife-recreation information summarized at a local scale to best manage recreation, conserve wildlife, and advocate for effective policy (Miller et al. 2020). The need for targeted, local scientific review of wildlife-recreation research is particularly important for the western United States, which holds both the largest percentage of public lands and protected wildlife habitat, and is experiencing some of the highest population growth rates. Washington State has the second largest population in the West (7.7 million people and growing), and its primary metropolis, Seattle, has consistently been one of the fastest growing cities in the country (Morhman 2021). With nearly 19 million acres of public land and another 6 million acres of tribal land, Washington holds appealing opportunities for a growing number of outdoor recreationists and boasts a remarkable set of ecosystems, including temperate rainforests, glaciated alpine, and high desert biomes.



State of Washington land ownership and management

Recreational access to wildlife habitats in Washington is structured around road corridors, especially the three primary east-west highways (I-90, US-2, and WA-20) that provide access to the largest tract of public land in the state. This is important as the level of influence recreation exerts on an environment is closely linked to the accessibility of a given area to various recreation types. Indeed, roads and trails accessible to both motorized and non-motorized recreational activity can cause widespread patterns of wildlife displacement and avoidance behavior (Gaines et al. 2003). As a result, it is important to acknowledge how roads, trails, and their respective densities likely shape wildlife-recreation dynamics. Further, Miller et al. 2020 noted this is especially relevant for wildlife species that are habitat specialists, particularly sensitive to human disturbance, or both. For these species, recreation may compound the mounting effects of climate change and habitat fragmentation that animals are already experiencing.

Many of the species in this report exist at healthy population levels elsewhere in North America and the globe; however, their local status in Washington may be of concern. Therefore, it is critical to collate recommendations in the existing scientific literature and identify Washington-specific knowledge gaps to aid conservation practitioners in protecting habitat that supports robust wildlife populations while still accommodating outdoor recreation activities. Washington boasts myriad unique ecoregions, diverse wildlife communities, and remarkable opportunities for recreation; features that highlight the importance of a holistic understanding of the connections between wildlife and recreation. This report aims to provide a species-specific synthesis of recreation impacts for animals in Washington that are of particular interest to Conservation Northwest and reveal how animals may be responding to locally important types of recreation.

SUGGESTED READING

Title	Authors
The “Recreation Boom” on Public Lands in Western Washington: Impacts to Wildlife and Implications for Treaty Tribes	Nelson and Bailey 2021
Sustaining wildlife with recreation on public lands: a synthesis of research findings, management practices, and research needs.	Miller et al. 2020
Off-highway vehicle recreation in drylands: a literature review and recommendations for best management practices	Switalski 2018
Hiking, mountain biking and equestrian use in natural areas: a recreation ecology literature review	Hennings 2017
Effects of recreation on animals revealed as widespread through a global systematic review	Larson et al. 2016
Does rock climbing threaten cliff biodiversity?	Holzschuh 2016
Snowmobile best management practices for Forest Service travel planning: a comprehensive literature review and recommendations for management.	Switalski 2016
The effects of winter recreation on alpine and subalpine fauna: a systematic review and meta-analysis.	Sato et al. 2013
Recreationist behavior in forests and the disturbance of wildlife	Marzano and Dandy 2012
A review of the impacts of nature-based recreation on birds	Steven et al. 2011
Ungulate flight response to human disturbance: a review and meta-analysis.	Stankowich 2008
Assessing the cumulative effects of linear recreation routes on wildlife habitats on the Okanogan and Wenatchee National Forests	Gaines et al. 2003
The effects of non-consumptive wildlife tourism on free-ranging wildlife: a review	Green and Higginbottom 2000

ABOUT THIS REPORT

The scope of this report is focused on the effects of year-round, terrestrial motorized and non-motorized recreational activities on terrestrial mammal and bird species. This focus extends only to upward-trending non-hunting recreation activities, as effects on wildlife from hunting are already closely regulated by federal, state, and tribal agencies. Additionally, hunter numbers in Washington have been declining for decades, unlike other recreation activities across the state. Species included in the scope of our literature search were identified as priorities by Conservation Northwest based on their local conservation status and importance to stakeholder groups in Washington state (Table 1). Where appropriate and consistent within the existing body of recreation and wildlife review papers, we have included information from studies of European populations and of closely related species within the same genus. While information gained from members of the same species in Europe can lend valuable insight to impacts of recreation on North American species, we caution that European populations have occurred in areas with relatively high human densities far longer than North American counterparts and often still experience greater levels of human exposure. As a result, these animals could display higher levels of habituation or adaptation not applicable to animals in North America. Inferences drawn from North American studies conducted outside of Washington, and especially those outside of the Pacific Northwest, should also be interpreted with caution. Similarly, studies of different species within the same genera can provide important information about how a species of interest may respond to recreation; however, it is important to note that interspecific differences are present. Closely related species often vary in numerous ways, including behaviorally and in their foraging and reproductive strategies, thus direct comparisons should be carefully considered.

We searched the Web of Science Core Collection using the Boolean search string “wildlife AND recreation” to identify relevant literature. From this search we curated an initial list of articles written in or translated to English (n=1,795) for which abstracts were screened to exclude articles outside the scope of this report. This screening resulted in a list of 99 papers of both white and gray literature for full review. Due to both time constraints and the amount of literature available for a given species, we narrowed the scope of this report to a subset of species of interest (Table 1), which resulted in inclusion of 66 papers from the list of papers for full review. We used a snowball technique to identify additional pertinent publications by reviewing the literature cited in each of the papers included in our full review. Using this snowball technique, we reviewed and included an additional 50+ scientific articles related to the impacts of recreation on our species of interest.

Species	IUCN status	US status	WA status
Bighorn sheep *(Ovis canadensis)*	LC		SGCN
Caribou *(Rangifer Tarandus)*	VU	EN	EN
Elk *(Cervus canadensis)*	LC		
Mountain goat *(Oreamnos americanus)*	LC		PS
Mule deer *(Odocoileus hemionus)*	LC		PS
Black bear *(Ursus americanus)*	LC		
Canada lynx *(Lynx lynx)*	LC	TH	EN
Grizzly bear *(Ursus arctos)*	LC	TH	EN
Mountain lion *(Puma concolor)*	LC		
Wolf *(Canis lupus)*	LC	UR	EN
Wolverine *(Gulo gulo)*	LC	UC	SGCN
Bald eagle *(Haliaeetus leucocephalus)*	LC		SGCN
Golden eagle *(Aquila chrysaetos)*	LC		SGCN, PS
Marbled murrelet *(Brachyramphus marmoratus)*	EN	TH	EN
Sage grouse *(Centrocercus urophasianus)*	NT		EN

<< Table 1
Global (IUCN), federal, and state conservation statuses for species included in this report. LC= Least Concern, NT= Near Threatened, TH= Threatened, VU= Vulnerable, EN= Endangered, UR= Under review, UC= Under consideration, CA= Candidate, SGCN= Species of Greatest Conservation Need (under the Washington State Wildlife Action Plan), PS= Priority Species (under the Washington Priority Habitats and Species Program).

Colors indicate relative level of conservation concern, with green representing species of least concern, yellow moderate concern, purple high concern, and red extreme concern.

Species accounts are listed alphabetically according to taxonomic family. Each species account provides relevant ecological history, geographic range, literature findings, and implications for best management in Washington. Literature summaries for each species incorporate as much applicable science as possible including recreation type (e.g., hiking, snowmobiling, etc.), response type (e.g., behavioral, physiological, distribution, reproduction), and effect scale (e.g., community, population, individual). Each account concludes with a discussion of areas for future research and special recreation coexistence considerations for each species in Washington. Appendix A summarizes possible conservation implications gleaned from our review of the literature. This table serves as a quick reference for readers but should not be interpreted out of context; it is important to read the individual species accounts to fully understand and interpret possible mitigation measures for areas where wildlife and recreation conflict exist.

Coarse spatial overview of recreation overlap within each species' range were based on comparison of best available species maps with data from Washington Hometown recreation maps, maps of local trail networks, and personal knowledge of recreation areas. There was no single source for species maps, so we prioritized data from sources in the following order: 1) Habitat Concentration Areas (Washington Wildlife Habitat Connectivity Working Group [WWHCWG] 2010); 2) designated recovery areas (United States Fish and Wildlife Service, USFWS); 3) maps of current distribution or important habitat areas (Washington Department of Fish and Wildlife [WDFW]); 4) Nature Mapping; and 5) BirdWeb. Detailed accounts of areas where each species overlaps with different recreation types were beyond the scope of this report and should not be considered complete; however, for the purposes of this report we offer this coarse spatial overview both to highlight local areas of overlap in Washington and suggest areas for management and conservation focus.

BIGHORN SHEEP

(*OVIS CANADENSIS*)

Bighorn sheep (*Ovis canadensis*) iconically inhabit steep, rocky and rugged terrain; however, they also exist in alpine meadow, shrub-steppe, mixed woodland and prairie ecosystems. Like many ungulates, bighorn sheep migrate seasonally from higher elevations in the summer to lower elevations in the winter and are most often restricted to elevations of 1,000 ft.-7,000 ft. between seasons (Johnson and Lockard 1983). In Washington state, there are 17 managed herds that inhabit a limited range and are most commonly found east of the Cascade crest between Wenatchee and Chelan, as well as in the far northeast and southeast corners of the state.

LITERATURE FINDINGS

The majority of scientific literature measuring the response of bighorn sheep to recreation examines behavioral changes displayed by specific populations in the western portion of the United States and Canada. However, comparable studies on other *Ovis* species have been performed elsewhere, and are included here where applicable. Limited information is available on physiological responses (e.g., heart rate) or population dynamics, and although Switalski et al. 2018 considered vehicular traffic impacts to bighorn sheep, we found no studies specific to motorized recreation.

Increased vigilance, flight, and spatial adjustment over time are well documented effects of human disturbance on bighorn sheep. Several studies examine the difference in responses between bighorn sheep populations where recreation intensity differs between herds. Both Sproat et al. (2019) and Reimers et al. (2003) found that sheep in high-recreation areas responded more severely to disturbance than sheep in low-recreation areas, and Sproat et al. (2019) documented a significant increase in vigilance leading to a decrease in grazing and other survival activities. These highly disturbed populations are also hunted and are therefore more sensitive to disturbance year-round (King 1985, Stankowich 2008). Indeed, male mouflon sheep (*Ovis gmelini*) exposed to both tourism and hunting in southern France moved longer distances between resting and foraging areas after disturbance than a neighboring population that experienced only tourism (Marchand et al. 2014). This stronger response to sustained disturbance may result in more energy expenditure overall if nutrition, rest, or reproductive losses occur.

Hiking, especially off-trail, is the most disturbing recreational activity of those studied in bighorn sheep, likely due to the unpredictable nature of approach (Papouchis et al. 2001, Stankowich 2008). In Alberta, changes in heart rate and behavior of sheep exposed to experimental hiking trials showed a larger impact from unpredictable activity, where humans approaching on foot were more disturbing when they were off-trail and/or at a higher elevation than sheep (MacArthur et al. 1982). Rugged, high-elevation escape terrain is important to bighorn sheep (Geist 1971, Holl 1982, VanDyke et.al 1983, Dunn 1996, Frid 2003), so disturbances from above can barricade sheep from fleeing to more secure habitat. Bighorn sheep sensitivity to non-motorized recreation was also examined on winter range overlapping with recreational backcountry skiing in Wyoming, where sheep avoided areas of high-quality habitat entirely at any level of recreation, even when recreationists were not actively using the area (Courtemanch, A.B. 2014). Although not as disturbing as hiking (Papouchis et al. 2001), mountain biking can also entirely displace sheep populations from areas where the activity occurs (Lowrey and Longshore

2017). Thus, spatial and topographic separation, in combination with available escape terrain, is important for bighorn sheep tolerance of recreational activities (Hicks and Elder 1979, Courtemanch, A.B. 2014).

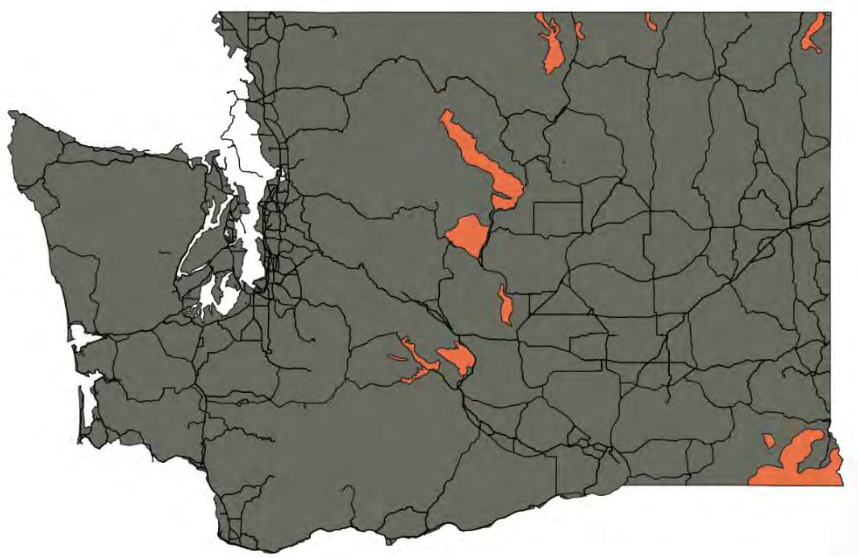
Shifting activity patterns temporally is another common response of sheep to recreational disturbances. In Joshua Tree National Park, spatial data from female GPS-collared desert bighorn sheep showed a shift away from trails during the day, as well as during days of the week with higher recreation intensity (Longshore et al. 2013). Similarly, Marchand et al. (2014) found a significant reallocation of sheep activities from daytime to nighttime to avoid temporal overlap with recreationists. Season also affects the impact of recreation on bighorn sheep; males are more sensitive during the fall breeding season when hiking activity is more abundant (Papouchis et al. 2001), while female sheep are highly disturbed by recreation during the lambing season (Papouchis et al. 2001, Wiedmann and Bleich 2014). Although both sexes increased vigilance behavior during experimental hiking trials in a study of Dall sheep (*Ovis dalli*) in Yukon, Canada, females also decreased resting and foraging (Loehr et al. 2005). Dimorphic responses should be carefully considered for breeding populations of sheep since altered female spatial patterns can result in the loss of lambing habitat. For example, in North Dakota, female sheep experienced seasonal displacement or complete abandonment of preferred lambing habitat in response to high recreation levels, and reproduction success fell by 38% (Wiedmann and Bleich 2014). In comparison, another sheep population in their study that experienced less recreation continued to grow.

Although few studies provided information on the impact of recreationists accompanied by dogs on bighorn sheep, it is worth noting that increased heart rate and longer flight distances were observed when humans approached sheep with a leashed dog, even on-trail (MacArther et al. 1982). Similarly, mouflon sheep stayed twice as far from hikers with dogs than hikers without dogs (Martinetto and Cugnasse 2001).

KEY POINTS

- Female bighorn sheep tend to be more sensitive to recreation than males, especially during the **lambing season**
- Adequate habitat that includes **nearby escape terrain is essential** for sheep, especially females with young
- Disturbance during the lambing season may **entirely displace reproducing females from high quality habitat** and lead to a **decrease in reproduction success**
- Activity at **elevations above** sheep is more disturbing than below

IMPLICATIONS FOR BIGHORN SHEEP IN WASHINGTON



Bighorn sheep habitat concentration areas

Source: WWHCWG 2010

Although bighorn sheep habitat is often difficult for most recreationists to access due to its steep and rocky terrain, most bighorn sheep habitat in Washington occurs on public land and is therefore available to backcountry recreationists and subject to various sources of both direct and indirect recreational pressures. Most notably, hiking and mountain biking (often on shared-use trails) are extremely popular and accessible activities in bighorn sheep habitat along the I-90 and US-2 corridors. Rock climbing is also common along the Columbia River between Leavenworth and Vantage, an area where bighorn sheep are often observed even from roadways. Bighorn sheep likely encounter a small amount of motorized recreation in distinct areas of Washington as well, though there is no existing literature about how motorized activities may be impacting bighorn sheep. Additional research is needed on mountain biking to properly address the impacts of this activity before considering expansion into bighorn sheep habitat. Similarly, we found no research on the effects of rock climbing on bighorn sheep, an activity that is growing in popularity, occurs frequently in sheep habitat, and has the potential to overlap closely with individual populations. However, despite the lack of known impacts on bighorn sheep from rock climbing and mountain biking, it is clear that similar recreation activities produce negative effects.

Several studies show that bighorn sheep are especially sensitive to high intensities of recreation during lambing season and can be displaced from important lambing habitats, resulting in decreased reproduction. These studies highlight the need for discovering if and where similarly high levels of recreation in Washington overlap with lambing habitat. For these areas, seasonal closures of lambing habitat are recommended by the literature (Papouchis et al. 2001). Furthermore, winter is a sensitive time for bighorn sheep when low levels of off-trail backcountry skiing can cause sheep to entirely avoid high-quality habitat (Courtemanch, A.B. 2014). Thus, areas of overlap between winter recreation and sheep wintering areas should also be identified. Restricting recreation in these areas could be considered to mitigate the risk of displacing sheep from winter habitat. Other management recommendations from the literature for reducing recreation impacts on bighorn sheep include enforcing strict regulations of off-trail travel in sheep habitat, and protecting easily accessible, high-quality escape terrain for sheep by directing trails away from these areas (Hoglander et al. 2015).

CARIBOU
(*RANGIFER TARANDUS*)

Washington no longer supports a population of woodland caribou (*Rangifer tarandus caribou*) or its unique ecotype, mountain caribou. The last remaining member of the South Selkirk subpopulation in eastern Washington, which was also the last wild caribou in the lower 48 United States, was relocated to British Columbia in 2019. Unique behavioral characteristics place the mountain caribou at increasing risk for extinction in the face of habitat destruction and climate change. Caribou populations have been declining throughout their North American range for decades, where caribou historically spanned the US-Canada border into eastern Washington, central Idaho, and western Montana.

LITERATURE FINDINGS

The body of scientific literature addressing caribou is extensive, with all relevant studies taking place in Canada, Norway, and Greenland. These studies focus on behavioral responses and distributional changes of specific populations in relation to recreation activities with a heavy emphasis on winter impacts. Although several subspecies of caribou are discussed in the literature, this report will refer to the *Rangifer tarandus* species as a whole. Many experimental treatments of human disturbance to caribou are examined in the context of hunting and are beyond the scope of this report, however these results will be included where they apply to broader recreation impacts.

Caribou have been predominantly studied in the winter because of their northern distribution and largely boreal habitat requirements; however, responses of caribou to winter recreation generally appear to be less severe than in the summer (Reimers et al. 2010), but vary with activity. Caribou approached experimentally by researchers on skis and snowmobiles in Norway fled at shorter distances and traveled farther from disturbance in response to skiers as compared to snowmobilers, presumably because of their ability to detect and observe snowmobiles approaching from farther away (Reimers et al. 2003). Mahoney et al. (2001) also approached caribou with snowmobiles directly and found that responses varied depending on group composition and snow conditions, where cows with calves waited the longest to respond to provocation and individuals of all sexes delayed their response when snow was deepest. Tyler (1991) suggests that speed of approach is the main factor in determining whether caribou will flee, with faster vehicles causing greater disturbance. For example, snowmobiles were slower and less disturbing in Tyler's (1991) study than in a vehicular study by Horejsi (1981). Common behavioral responses to disturbance include increased vigilance and flight, both of which can have physiological consequences and be detrimental to individual animals (Aastrup, P. 2000, Wolfe et al. 2000, Reimers et al. 2006), especially in severe winter conditions (Duchesne et al. 2000). The tendency of caribou and other ungulates to escape disturbance by moving uphill may also increase the physiological stress of repeated flight behaviors (Reimers et al. 2006). Furthermore, caribou exposed to guided wildlife-viewing groups during winter in Quebec, Canada, were significantly more disturbed by groups greater than nine people, demonstrating increased vigilance and decreased time spent resting, ruminating, and foraging (Duchesne et al. 2000). On a population level, caribou in British Columbia were found most often in areas with little to no snowmobile activity and rarely in areas that permitted snowmobiles (Seip et al. 2007). Individuals found near high snowmobile activity stayed two km away from snowmobiles and were separated from disturbance by a ridgeline, suggesting caribou seek refuge in habitats with natural protective buffers. Seip et al. (2007) concluded that by shifting caribou spatially, snowmobiles displaced caribou from high-quality to lower quality habitat, and this displacement could place caribou at a significantly higher mortality risk. Furthermore, a literature review by Wolfe et al. (2000) notes that space-use impacts to individuals can affect caribou at the population level depending on the availability and condition of disturbance-free habitat options.

Caribou studies report mixed responses to recreation during the calving season. For example, Lesmerises et al. (2017) used data from trail cameras, individual observations, and GPS-collared female caribou to examine the difference in the response of cows with and without calves to hikers. Overall, both groups stayed farther from the trail when being used by hikers, but the groups displayed different rates of vigilance. Cows with calves within 500 m of the trail decreased vigilance as the number of users increased, while calf-less cows increased vigilance under the same conditions. The authors suggest that decreased vigilance in cows with calves could be because of the predation refugia human activity creates. For cows with calves, decreasing vigilance in predation refugia allows increased nutritional intake which is important to successful calf rearing.

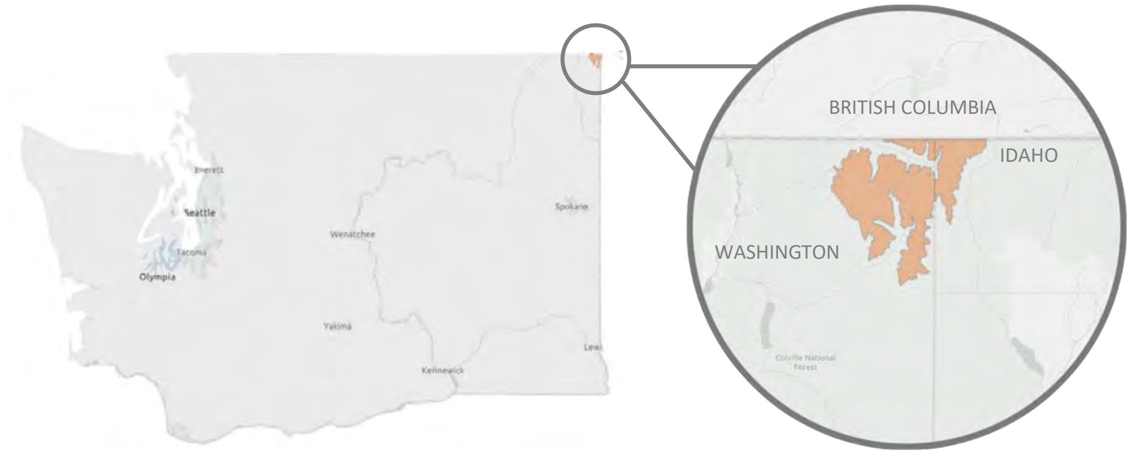
Under different circumstances, Aastrup (2000) found that when approaching groups of caribou on foot and off-trail in Greenland, caribou had a significantly higher rate of vigilance and farther flight distances in groups with calves as compared to groups in the post-calving season. Although these studies suggest that cows with calves differ in their sensitivity to recreation situationally, Reimers et al. (2006) suggested establishing a buffer distance of at least 350 m from reindeer (Rangifer tarandus tarandus) during calving when the risk of energetic expenditures in response to disturbance are highest. Caribou show diverse responses to recreational disturbance depending on season, activity, and intensity of use, with some evidence that caribou habituate to recreation (Geist 1971, Colman et al. 2001, Mahoney et al. 2001, Reimers et al. 2006 and 2010). Colman et al. (2001) found decreased sensitivity in a population of Svalbard reindeer (*Rangifer tarandus platyrhynchus*) exposed to recreational activities year-round (hiking, hunting, and skiing), as compared to a population with fewer recreational disturbances. A comparison of two other reindeer (*Rangifer tarandus tarandus*) populations on Norway's mainland, one with high human activity and one with little to no human activity, showed similar habituation behaviors in the more regularly disturbed group (Reimers et al. 2010). However,

KEY POINTS

- Caribou are especially sensitive to recreation during the **calving season**
- Caribou are highly disturbed by **less predictable** forms of recreation (off-trail, quiet)
- Caribou are easily displaced by **snowmobiles**, resulting in the loss of access to high-quality habitats and potentially increasing mortality risk

repeated exposure and responses of caribou to disturbances, even when indicating decreased sensitivity, can still result in energy expenditure and lead to increased susceptibility to predation, nutritional deficits, and reproductive failure (Reimers et al. 2006). It is important to note that habituation studies have only been conducted outside of North America and could produce conflicting results when repeated in the US or Canada.

IMPLICATIONS FOR CARIBOU IN WASHINGTON



Historic (up to 2019) woodland caribou range

Source: USFWS accessed and modified 2/25/22

If caribou are reestablished in the contiguous United States, the current science supports managing recreational activities in their historical range, especially relating to snowmobiling. The literature suggests encouraging use of trail systems that are already established and, where necessary, placing new trails in low-elevation terrain such as valley bottoms, as well as restricting use of snowmobiles in high-quality caribou habitat (Reimers et al. 2003, Seip et al. 2007). High-quality habitat is essential for escaping disturbance and in areas where snowmobiling is permitted, adjacent caribou refugia habitat should be protected from recreation. Additionally, even quiet and slow activities are highly disturbing to caribou, therefore non-motorized and shared-use trails should also be spatially limited and restricted to on-trail use to conserve important refugia habitat. As cows with calves can be especially sensitive to disturbance, spatial buffers of at least 350 m and seasonal trail closures may be implemented in calving and rearing areas, especially during high snow years when flight is more energetically costly (Reimers et al. 2006). Further research on the impacts of other types of recreation on caribou, specifically hiking, mountain biking, and ORV use is also needed. Information on the impacts of these increasingly popular activities will greatly contribute to caribou management if/when this species returns to Washington.

ELK

(*CERVUS CANADENSIS*)

Elk (Cervus canadensis) occur as a healthy population throughout Washington state and are divided into two subspecies: Roosevelt Elk (Cervus canadensis roosevelti) west of the Cascade crest and Rocky Mountain Elk (Cervus canadensis nelsoni) east of the Cascade crest. Olympic National Park, Mount Rainier National Park, and surrounding National Forests comprise a significant portion of elk range on the west side of the state, with the Umatilla National Forest, Colville National Forest and private timber land hosting the easternmost populations. Elk typically require a combination of grassy meadow, shrub-steppe, or regenerating forest openings within a patchwork of mature forest cover. Elk require lower elevation, valley bottom habitat for winter range, as snow level limits foraging opportunities at higher elevations.

LITERATURE FINDINGS

Much of the existing scientific literature examining elk responses to recreation consider the behavior of elk in response to recreation, with only a handful of studies reporting physiological changes (e.g., stress hormone levels) or impacts on reproduction. Most studies documented impacts of either on-trail or off-trail recreation for both motorized and non-motorized activities. North American elk have been studied extensively in the western United States and Canada, but a greater variety of information has been produced on red deer (*Cervus elaphus*) in Europe and, as such, is included here where applicable.

Common behaviors exhibited by elk and red deer in response to recreation and reported in the literature include vigilance, avoidance, and flight. These behavioral responses cost elk time spent on other survival activities (e.g., foraging, resting) and direct energy expenditure when fleeing the area (Cassirer et al. 1992, Harris et al. 2013). Although several studies document evidence that ungulates can achieve some level of behavioral habituation to recreational activities (Colman et al. 2001, Stankowich 2008, Reimers et al. 2010), Creel et al. (2002) showed glucocorticoid levels (a stress hormone, e.g., cortisol) in fecal pellets collected from elk in Yellowstone National Park were significantly higher as a result of snowmobile disturbances in comparison to wheeled-vehicle (spring and summer) disturbances, and these levels continued to increase as the intensity of over-snow travel increased (see also Larson et al. 2016).

In contrast, cortisol levels differed between the fecal pellets of red deer collected from two herds in an urban park in the United Kingdom, with those regularly exposed to human activity having less fecal cortisol than individuals from the herd that rarely encountered human visitors (Dixon et al. 2021). This phenomenon of higher sensitivity in less disturbed populations has been well documented in behavioral studies across a variety of taxa (MacArther et al. 1982, King 1985, Stankowich 2008, Reimers et al. 2010, Harris et al. 2013, Westekemper et al. 2018,). For example, Westekemper et al. (2018) applied experimental hiking treatments to red deer in Germany and found a significant difference in the flight initiation distance of those approached on-trail (predictable) vs off-trail (less predictable), with off-trail activity evoking a stronger response. Not only did red deer initiate flight from off-trail disturbance at longer distances, their total distance traveled was also farther. On-trail treatments did not elicit significant flight responses from red deer, although some traveled short distances and remained vigilant. Elk in Alberta, Canada and red deer in Scotland increased vigilance in response to activities during the hunting season as off-trail hiking on public lands became more frequent, and elk used refugia on private and protected lands where human activity was more predictable (Jayakody et al. 2008, Ciuti et al. 2012).

While increased vigilance and travel away from disturbances may have short term impacts on the fitness of individual elk, little is known about how these changes in behavior might affect individual fitness or the population as a whole. Phillips and Alldredge (2000) and Shively et al. (2005) produced consecutive studies that examined reproduction in a population of elk in Colorado during and after experimental off-trail hiking treatments. Results from the treatment period showed a significant decline in reproduction and population growth when >10 off-trail disturbances occurred during the calving season (Phillips and Alldredge 2000). In the two years following the cessation of hiking treatments during the calving season, calf production increased (Shively et al. 2005). Together, these results indicate that off-trail and unpredictable forms of recreation have negative population-level impacts on elk.

Predictable forms of recreation are generally better tolerated by elk but the type, speed, duration, intensity, time of year, and distribution of these activities can have a significant impact on the variability of their response (Stankowich 2008, Larson et al. 2016). Both elk and red deer will alter their distribution to avoid the highest recreation levels during the daytime and on weekends. Studied individuals consistently maintained a higher degree of separation from recreational trails during the day and shifted closer to trails at night (Ferguson and Keith 1982, Coppes et al. 2017, Westekemper et al. 2018, Scholten and Hegland 2018); this trend has also been seen in other species (Longshore et al. 2013, Marchand et al. 2014, Gaynor et al. 2018, Nix et al. 2018). When elk and red deer were found closer than expected to trails during the day, researchers usually attributed it to vegetative or topographical visual buffers between the animals and the trail (Cassirer et al. 1992, Jayakody et al. 2008, Stankowich 2008, Sibbald et al. 2011, Coppes et al. 2017, Wisdom et al. 2018). However, because elk generally prefer open grassland or shrubland for foraging, seeking the safety of cover habitats when near to recreationists may reduce time spent foraging in preferred habitats.

Similarly, elk and red deer were found farther from trails on weekends when recreation intensity was highest, as compared to weekdays when recreation intensity was lowest (Ferguson and Keith 1981, Sibbald et al. 2011, Nix et al. 2018, Dixon et al. 2021). Based on spatial data from global positioning system (GPS)-collared red deer in Scotland, individuals also moved farther distances between 2-hour GPS fixes on Sundays than on Wednesdays, indicating that red deer traveled more on days with more trail users (Sibbald et al. 2011). In addition, the distance between these red deer and the trail was farthest at 10:00 am, corresponding to a substantial peak in trail users. Furthermore, Nordic skiers in Alberta reported wildlife encounters (including elk) in a 1979 survey, with more encounters during the week than on weekends, perhaps indicating increased comfort of wildlife on days with fewer visitors (Ferguson and Keith 1981). In the United Kingdom, Dixon et al. (2021) observed higher fecal cortisol levels in red deer on days with more park visitors (Sundays) than on days with less visitors (Tuesdays) among herds that were both conditioned and unconditioned to human interaction. These physiological results again suggest that although elk are able to respond spatially and temporally to fluctuations in recreation intensity, they still exhibit some level of stress associated with these changes.

Data from a study by Westekemper et al. (2018) showed that red deer with lower trail densities within their home range stayed farther from trails while red deer with high trail densities within their home range spent time closer to trails. This result may indicate that red deer exposed to higher levels of recreation experience habituation, or it may simply be a function of the amount of habitat available between trail systems (Stankowich 2008, Westekemper et al. 2018).

Extensive research examines the impact of various recreational activities to elk at the Starkey Experimental Forest and Range Facility in eastern Oregon. Most notably, experimental treatments of hiking, mountain biking, horseback riding, and all-terrain vehicle (ATV) operation were analyzed, with the effects of ATV operation being significantly more pronounced than the others, followed by mountain biking, hiking, and horseback riding, respectively (Preisler et al. 2006, Naylor et al. 2009, Wisdom et al. 2018). While elk responded to all activities by moving away from the disturbance, elk traveled farthest from trails, rested longer after travel, and spent less time foraging following ATV disturbance (Naylor et al. 2009). Furthermore, animal responses to ATVs were significantly higher when the disturbance was near (e.g., 20 m) rather than far (e.g., 500 m), although responses were still observed from ATV disturbances up to 2 km away (Preisler et al. 2006). Recreation treatments were performed over several days, during which elk avoided disturbance by persistently staying farther from trails and seeking vegetative or topographical cover, but returned to their normal distribution in the days following the cessation of treatments (Naylor et al. 2009). The authors note that although this could appear to be an adaptive behavior, careful attention should be paid to the indirect costs associated with loss of valuable habitat that occurs when elk avoid recreation corridors while in use.

ATVs were also found to be particularly disturbing to elk in a study by Ciuti et al. (2012) where vigilance behaviors notably increased while foraging and grooming behaviors decreased when exposed to ATVs. Less literature exists on the impact of similar winter motorized activities (e.g., snowmobile); however, Borkowski et al. (2006) found that in Yellowstone National Park, where snowmobiling is permitted on certain routes, the majority of elk within 500 m of the road responded to approaching snowmobiles by increasing vigilance and/or fleeing from the disturbance, thereby increasing energy expenditure and potentially displacing elk into less desirable habitats.

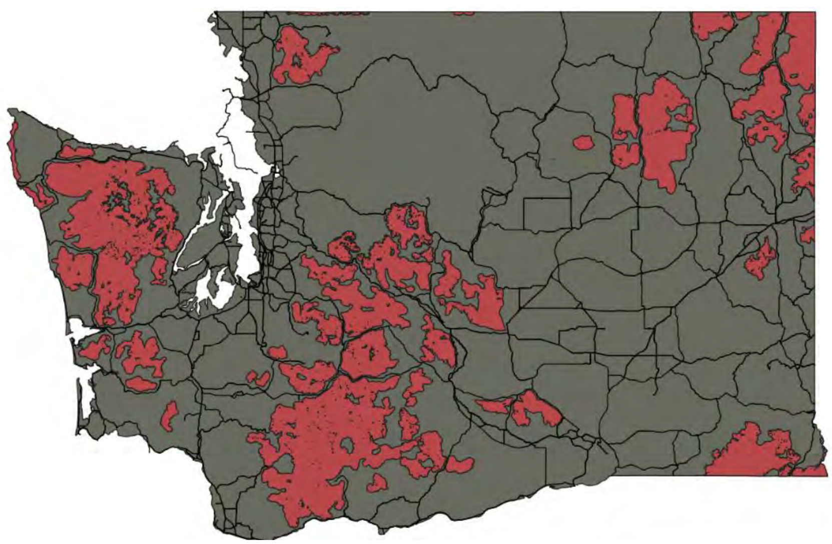
Although the extensive body of elk-recreation research is dominated by ATV impacts, several studies have been conducted with a focus on non-motorized, trail-based activities (hiking, mountain biking, and nordic skiing) and should

KEY POINTS

- Female elk are especially sensitive to recreation during **calving season**, when repeated disturbances can lead to decreased calf production
- Elk will shift activities temporally to avoid recreation, so **refugia during crepuscular and nocturnal hours** is especially important
- Elk respond negatively to **ATV use,** fleeing at longer distances and maintaining a high degree of separation from trails even after disturbance has ceased

also be considered. Using fecal pellet counts from red deer near mountain biking trails in Norway, Scholten et al. (2018) found a decrease in occupancy within 40 m of trails, with a higher concentration of pellets at 40 m where red deer presumably observe and make decisions around interacting with the trails, and a lower concentration of pellets (e.g., more spread out) beyond 40 m where deer are thought to be more comfortable and willing to disperse. Similarly, using data from GPS-collared elk, Rogala et al. (2011) found a 50 m buffer within which elk completely avoided roads and trails. Some attraction to a buffer zone of 51-400 m occurred during low recreational use, in which elk are thought to use this area as refuge from natural predators who avoid these recreation corridors. However, as recreation intensity in this study increased to two or more trail users per hour, elk avoided this buffer zone entirely. Likewise, a larger buffer of 401-800 m was attractive to elk when trail use was low, but was avoided altogether when 12 or more trail users per hour were present. Flight from nordic skiers in Yellowstone National Park occurred primarily within 650 m from elk, suggesting a buffer of this distance would limit the majority of responses, and a larger buffer of 1,700 m or more would likely eliminate any disturbance to elk (Cassirer 1992).

IMPLICATIONS FOR ELK IN WASHINGTON



Elk habitat concentration areas

Source: WWHCWG 2010

The current elk distribution in Washington overlaps with all types of recreation studied in the literature, with special concern for those populations in the south-central Cascades and northeast parts of the state where motorized recreation is widely permitted and use is heavy. For example, off-road vehicle (ORV) (including ATV) use on the Colville National Forest is popular during the spring, summer, and fall months, with concentrated snowmobile use during the winter season. Elk rely on meadows and openings which are also attractive for motorized recreation activities that can significantly damage these sensitive areas. In light of the literature findings that motorized recreation can negatively affect elk, management for these activities should be considered carefully.

Heavy shared-use recreation also occurs on federal land (e.g., Gifford Pinchot National Forest, Mount Rainier National Park, Mount St. Helens National Monument) and state-owned land (e.g., L.T. Murray Wildlife Area) on both sides of the I-90 corridor from Vantage to Snoqualmie, extending northward into Leavenworth and continuing as far south as the Washington-Oregon border. Although this area does impose some restrictions on ORV recreation, there is an extensive public road system that allows multiple types of access to the heart of elk range in this area. Public elk viewing is maintained in the Yakima Canyon at Oak Creek Wildlife Area.

Significant elk range also exists on the Olympic Peninsula where Olympic National Park provides protected habitat for elk. Motorized recreation is not permitted on trails within the park, but non-motorized recreation such as hiking, trail running, backpacking and mountaineering are popular throughout the park and surrounding areas.

Washington State boasts a healthy elk population that is important to sustain in part because of its high value to Tribes, land managers, recreationists and hunters alike. Because elk are particularly vulnerable to disturbance during calving season, important elk calving grounds that overlap with recreation should be identified and visitation could be limited during this time of year to reduce the risk of lowered calving rates. Additionally, the research demonstrates that elk experience negative impacts from recreation ranging from short term responses such as increased vigilance and flight, to avoidance of these otherwise suitable areas. Suggested management recommendations from the literature include educating recreationists on the impacts of their activities, enforcing strict trail guidelines (e.g., limiting off-trail travel, discouraging direct approach of elk), creating visual or spatial buffers between foraging areas and recreation corridors, and instating seasonal and/or nighttime closures where appropriate to provide elk with refuge from disturbance (Phillips and Alldredge 2000, Shively et al. 2005, Coppes et al. 2017, Westekemper et al. 2018).

MOUNTAIN GOAT
(*OREAMNOS AMERICANUS*)

In Washington, native mountain goat range falls primarily along the Cascade Mountain crest. Mountain goat habitat is restricted to open alpine areas, sparse, subalpine forests, and rocky cliffs which they use as escape terrain. Mountain goats also rely on salt lick sites for important minerals, showing strong site fidelity to specific licks throughout goat generations (Nelson and Bailey 2021). As habitat specialists with relatively small bands of suitable habitat, mountain goats are perhaps more susceptible to human disturbance than other ungulate species (Mountain Goat Management Team [MGMT] 2010, Richard and Côté 2016). This is particularly true in areas with limited escape terrain (Miller et al. 2020). Winter is a particularly vulnerable time for mountain goats since their habitat is further restricted to areas of less snow and adequate forage (Cadsand 2012).

LITERATURE FINDINGS

The majority of published literature related to mountain goats and recreation regards helicopter disturbance with either direct or indirect implications for heli-ski activities that overlap with mountain goat winter habitat. In some areas of their range, recreation, including increased heli-skiing in British Columbia and increased snowmobiling in Montana, are believed to be causing population declines (MGMT 2010, Cadsand 2012). Indeed, helicopter disturbance from energy industry activities was related to decreased breeding success for mountain goats in Montana (Miller et al. 2020).

In Alberta, Côté (1996) examined short-term behavioral response to summertime helicopter flights, which occurred multiple times per day. Mountain goats were classified as showing slight disturbance (alert for <2 minutes or moved <10 m), moderate disturbance (alert 2–10 minutes or moved 10–100 m), or strong disturbance (alert for >10 minutes or walked or ran >100 m; Côté 1996). Côté found that mountain goats were disturbed by 58% of helicopter flights, 26% of which were classified as strong disturbances. Helicopters that flew closer to mountain goats evoked a stronger reaction with 85% of flights within 500 m causing a strong reaction from the goats versus only 9% of flights >1,500m away evoking a strong response, however 28% of flights at >1,500 m still caused a moderate response. Mountain goat response did not depend on whether they were able to see the helicopter, just whether they could hear it (Côté 1996). Two decades later, Côté repeated observations of mountain goats and helicopters in the same area to test whether goats were becoming habituated to the disturbance (Côté et al. 2013). They found that mountain goats exposed to decades of helicopter flights showed minimal signs of habituation and displayed very similar baseline levels of disturbance response.

Short term responses to helicopters can deprive animals of time spent foraging, which can eventually decrease fitness (Cadsand 2012, Côté et al. 2013). Helicopter disturbance could also cause longer-term effects on movement rate and habitat selection. Cadsand (2012) looked at the rate of anomalous movements in the 48 hours after mountain goats were exposed to a heli-ski helicopter flight within 2 km of animals' initial position, as well as their habitat selection and movement rates during the heli-ski season. In the following summary of Cadsand's work, it is important to note the circumstances of disturbance under which the author's study took place: In response to concerns over helicopter flights disturbance to mountain goats, the heli-ski activities prior and during the time and place of Cadsand's study were restricted so that mountain goats were exposed to very little flight disturbance. Goats in this study experienced an average of <1 h per month of heli-ski flights, which were restricted to distances >1,500 m from a goat and explicitly avoided flying over or landing on mountain goat winter-range areas. Despite these precautions, Cadsand found that mountain goats increased movements in the 48 hours after exposure, were more likely to make anomalous movements after closer helicopter flights, and when the goat was farther away from escape terrain at the time of the flight. However, displacement or seasonal movement effects were not detected. Mountain goats in this study did not adjust habitat selection to avoid helicopter disturbance areas, but there was some evidence that when exposed to higher levels of heli-skiing flights, goats increasingly selected for escape terrain (Cadsand 2012). Cadsand attributes this relatively low response to the efforts put in place for mitigating mountain goat disturbance to helicopters. However, the author also notes that in contrast to Côté's study area in Alberta (described in the preceding paragraphs; Côté 1996, Côté et al. 2013), the terrain in their study area was much more rugged so that goats were often very close to escape terrain. Not needing to move long distances to reach escape terrain, these goats may have reacted more often to disturbance by staying in place and hiding, thus lowering movement rates. While staying in place may avoid energy expenditure, helicopters could still cause elevated stress levels in these situations (Cadsand 2012).

Developed ski areas can also impact mountain goats due to their increased human presence. Richard and Côté (2016) found that areas of high habitat quality within a developed ski area were never used in winter by collared mountain goats, although habitat just beyond the ski area boundary was. This displacement was only slightly less defined in the off-season despite no summer recreation, which the authors believe was a reaction to constant but low levels of ski-area maintenance activity (Richard and Côté 2016). In addition, Richard and Côté recorded the response of mountain goats to their presence when they were hiking within 1 km of goats. Of the 26 hiking trials, mountain goats always responded to their presence, even at the long-range distance of 1 km and females responded more strongly than males, exhibiting increased vigilance and moving away. In some populations, mountain goats have become habituated to predictable, non-threatening, regular human stimuli, which has led to higher human animal conflict and in some cases, dangerous interactions; such as the 2010 fatal goring of a hiker in the Olympic Mountains. Many other populations have not displayed

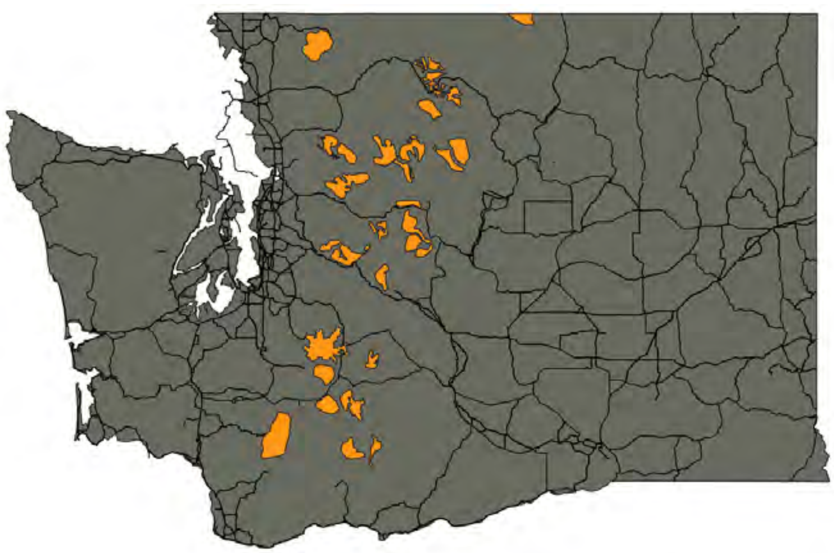
KEY POINTS

- Mountain goats can habituate to some forms of recreation, but for those populations that do not, recreation can have particularly negative effects since **mountain goats specialize on narrow bands of habitat with limited areas to seek refuge**
- Mountain goats are negatively impacted by the **sound of helicopters** and do not appear to habituate to this disturbance
- **ORVs have a negative effect** on mountain goats, especially when moving faster and directly towards goats

habituation and nannies appear to be the most sensitive to humans, especially during kidding season (MGMT 2010).

Many species react stronger to humans afoot than to humans using motorized vehicles (Stankowich 2008, Larson et al. 2016). In a study of behavioral responses in mountain goats to ORVs approaching within 1,500 m, goat groups were not or only lightly disturbed 55.7% of the time (alert for <2 minutes or moved <10 m) and were only strongly disturbed 22.9% of the time (alert for >10 minutes or walked or ran >100 m) (St.-Louis et al. 2013). However, when ORVs approached mountain goat groups directly rather than passing them at a parallel angle, goats were 31 times more likely to be strongly disturbed than lightly or not at all. Speed of ORV's also increased the disturbance level of goats; mountain goat groups were 6 times more likely to be strongly disturbed when ORVs approached at 25 miles per hour rather than 6 miles per hour. The authors of this study caution that the mountain goats in their study area have been consistently exposed to ORV's for decades so that their perception of ORVs as a threat may be lower than it would be for mountain goats in areas with less historic and regular ORV use (St.-Louis et al. 2013).

IMPLCATIONS FOR MOUNTAIN GOATS IN WASHINGTON



Mountain goat habitat concentration areas

Source: WWHCWG 2010

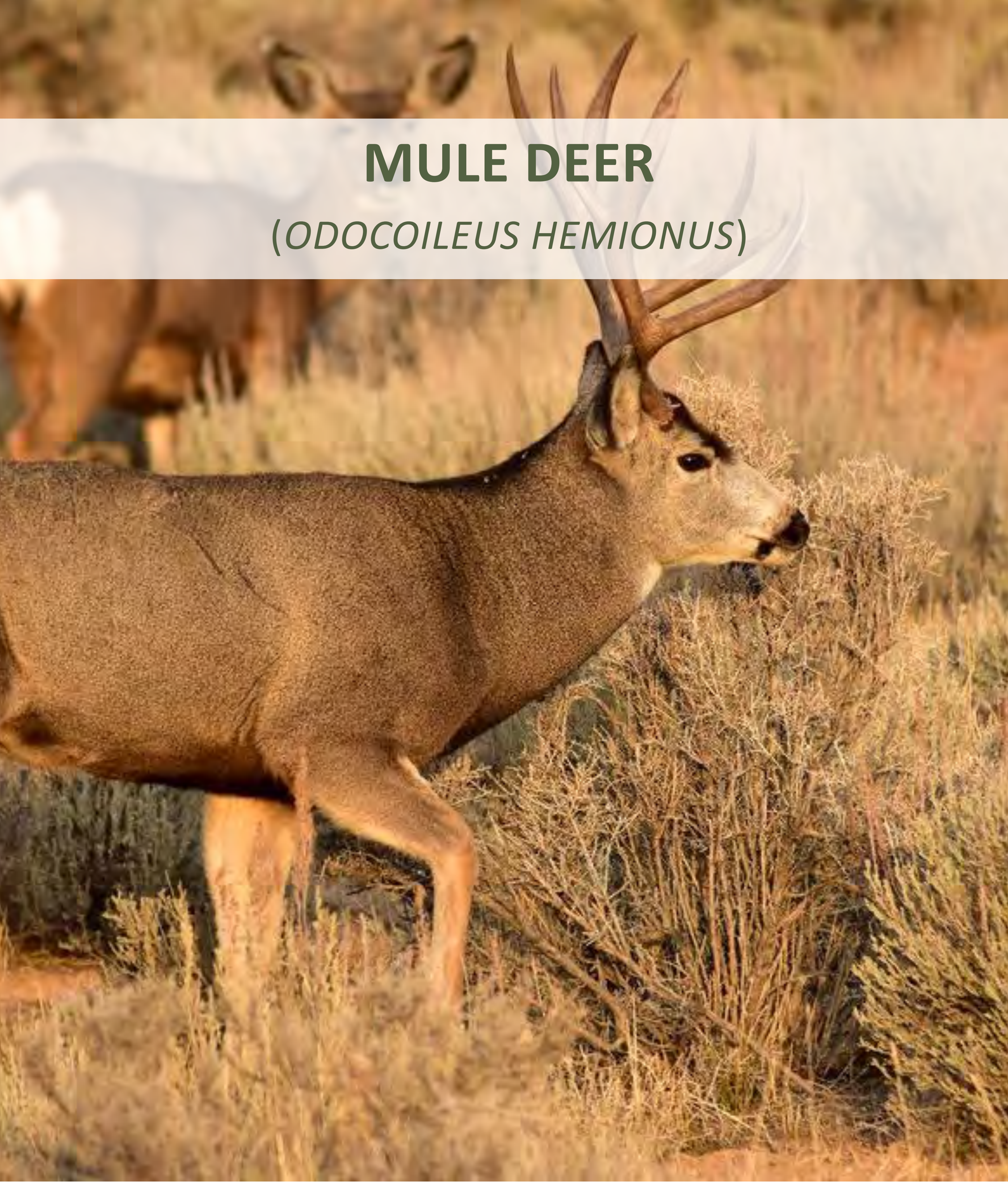
Alpine hiking trails traverse mountain goat habitat in Washington, with motorized trails existing in important mountain goat habitat along Harts Pass in the Methow Valley, between Cle Elum Lake and Kachess Lake, in habitat on the Tatoosh range south of Mount Rainier and in habitat south of Packwood (WWHCWG 2010). A detailed spatial analysis is required to assess if and where motorized roads overlap with mountain goat habitat. In winter, snowmobiling occurs along Harts Pass and WA-20 in the Methow Valley and around Cle Elum Lake. Heli-ski operations occur in mountain goat habitat from Mazama north along the WA-20 corridor to Beebe Mountain and northwest to the Pasayten Wilderness border. Heli-skiing also occurs up the Twisp River, east of Little Bridge Creek. In addition, backcountry skiing is popular in the Cascades along WA-20, Stevens Pass, Icicle Canyon near Leavenworth, Mount Baker, and the north side of Snoqualmie Pass. Of these, mountain goat habitat overlaps with Stevens Pass, Snoqualmie Pass, and Crystal Mountain ski resort.

Mountain goats may be particularly sensitive to winter recreation since their habitat at this time of year is restricted by snowpack. In Washington, locating areas of overlap between winter recreation and mountain goat range could be important for mitigating the potential impacts of recreation. In areas of high overlap, management recommendations from the literature suggest that recreation be seasonally limited in winter range. Furthermore, mountain goats are easily disturbed by helicopter flights, such as those used in Washington for heliskiing, and do not appear to habituate even after decades of exposure. Restricting helicopter flights to >1,500 m from mountain goats can reduce disturbance, although the degree to which these conditions can mitigate longer-term changes in movement patterns and habitat selection are unknown for areas with >1 hour per month of helicopter flight exposure. To mitigate possible negative impacts of heliskiing to mountain goats, managers should identify areas where goats are subject to higher levels of helicopter use and consider implementing restrictions to reduce the risk of disturbance in these areas in an adaptive management framework.

In addition to heliskiing where significant overlap between ORV use and mountain goat habitat may exist, ORV users should be discouraged from directly approaching mountain goats and should reduce their speed, as recommended by St.-Louis et al. (2013). Further, a review of management recommendations for mountain goats in British Columbia suggests that backcountry recreationists stay 1,500 m from goats to minimize disturbance, and that trails should be routed away from mountain goat winter range, kidding areas, and mineral licks (MGMT 2010).

MULE DEER

(*ODOCOILEUS HEMIONUS*)



Washington supports two subspecies of mule deer; the Columbian black-tailed deer (*Odocoilius hemionus columbianus*) on the western half of the state, and the Rocky Mountain mule deer (*Odocoilius hemionus hemionus*) on the eastern half. To avoid deep mountain snow, black-tailed deer in Washington migrate between high elevation summer ranges to lower elevation winter ranges. Black-tailed deer in low elevation areas such as the Puget Trough and coastal forests do not migrate. Rocky Mountain mule deer range spreads throughout much of eastern Washington with the largest migratory populations along the east slope of the Cascade Mountains. In the eastern Cascades, as well as in the Blue Mountains and to a lesser extent in mountainous areas of northeast Washington, many mule deer migrate between high elevation summer range and low elevation winter range. The Columbia Basin supports populations of non-migratory deer, though some winter-concentration areas do exist there.

LITERATURE FINDINGS

Much of the research on mule deer responses to recreation examines the distance at which mule deer become alert (alert distance) or flee (flight initiation distance) from a recreationist. The short-term behavioral responses of alertness and/or fleeing result in less time resting or feeding, and fleeing increases energy expenditure. These energy trade-offs are especially impactful in winter when snow impedes movement and ungulate survival depends on conserving energy. However, negative long-term effects do not necessarily always follow these short-term effects and more research is needed to examine the circumstances and recreation intensity thresholds under which increased alertness and fleeing impact mule deer survival.

Mule deer are known to habituate to humans so that their short-term behavioral responses to recreation are dampened in some cases (Price and Strombom 2014). In addition, if regular human presence in an area decreases predator abundance, mule deer may decrease their alertness and avoidance responses under these “safer” conditions (Price and Strombom 2014). Thus, the following summary of mule deer short-term behavioral responses to recreation should be interpreted with the understanding that short-term responses by mule deer may or may not lead to negative individual or population level impacts, and that in some situations, habituation or reduced risk of predation near humans might mitigate some of the fear-response effects of recreation on mule deer. For example, Price and Strombom (2014) performed 42 trials between on-trail walkers and deer around a small settlement in Colorado. They found that mule deer beyond 750 m of the settlement center fled at farther distances than mule deer closer to the settlement. Similarly, mule deer beyond 250 m of the settlement became alert at farther distances than mule deer within 250 m of the settlement. The authors discuss that these results could be evidence for mule deer habituation to humans, a response to lower risk of predation near humans, that bolder individuals may tolerate living nearer to humans than shy individuals, or a combination of some or all of these factors. Regardless of the mechanism driving lower reactions of mule deer within 750 m of the settlement, these findings have implications for recreation managers; recreation trails close to areas with existing human presence may have less effect on deer than trails farther from human activity centers.

A handful of studies also examine how different recreation types affect short-term behavioral responses in mule deer. Miller et al. (2001) performed experimental trials between mule deer and hikers. Hikers were with or without a leashed dog and experiments were performed both on- and off-trail. Their study found that the probability of becoming alert, the probability of fleeing, and the distance of flight increased when the hiker was off-trail vs on-trail, regardless of whether they were accompanied by a dog. The shorter the perpendicular distance between a deer and the trail (or a walker's line-of-movement for off-trail), the more likely a deer was to flee. Within on-trail and off-trail experiments, hikers with a dog on-leash evoked longer alert and/or flight distances and greater distances moved. In summary, hikers accompanied by a dog, even leashed, evoke a stronger response from mule deer and less predictable hiking (off-trail) evokes a stronger response yet. Further evidence for mule deer sensitivity to dogs was documented in a Colorado study where mule deer activity was significantly lower along trails and up to 100 m from the trail where dogs off-leash were allowed (Lenth et al. 2008).

Between hiking and mountain biking, Taylor and Knight (2003) found that mule deer in Utah expressed comparable alert distances and flight distances but moved somewhat farther in response to bikers (150 m as opposed to 115 m for hikers). Similar to other studies, this research also revealed that mule deer had stronger reactions to off-trail hiking and biking than to on-trail. In addition, larger human group-sizes, closer encounter distances, less vegetative cover, and disturbances above deer, rather than from below, elicited stronger responses. In a study of black-tailed deer, Stankowich and Coss (2006, 2007) found that deer fled sooner and further when pedestrians approached faster and directly towards the animal, and that deer tended to flee uphill and into taller vegetation.

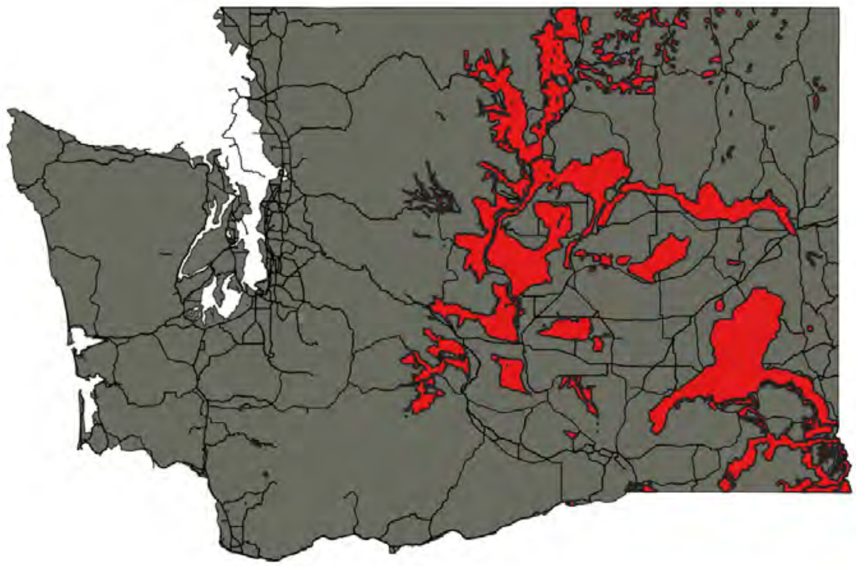
One of the trends among wildlife-recreation studies found by Larson et al. (2016) describes motorized recreation as generally less disturbing than non-motorized. For mule deer, this finding was validated in a study using GPS collars to estimate movement rates of mule deer undergoing experimental recreation trials compared to deer not undergoing trials (Wisdom et al. 2004). Hiking, biking, and horseback riding provoked higher movement rates than did ORV riding. Freddy et al. (1986) provide further evidence for higher sensitivity among mule deer to non-motorized recreation. Between experimental approaches of walkers and snowmobiles towards mule deer in winter, deer were more disturbed by walkers than snowmobilers. Specifically, mule deer responses to walkers were longer in duration, deer were more likely to flee, and most flight responses occurred within 191 m and 133 m for walkers and snowmobiles, respectively. Finally, in a study of black-tailed deer, OHV use did not significantly correlate with deer activity levels, home range size, diel patterns, or habitat selection. Black-tailed deer moved away from areas of OHV riding during peak use but returned once activity levels subsided (Ferris, 1989)

In addition to short-term responses of mule deer to recreation, studies show that mule deer shift their activities temporally to reduce human encounters (Lewis et al. 2021). Mule deer are typically most active in the mornings and evenings; however, when their activity patterns overlap with recreationists, shifting their activity patterns to nighttime can reduce overlap with human disturbance. Indeed, Lewis et al. (2021) found that in Colorado, mule deer did not spatially avoid areas with high levels of non-motorized recreation, rather they shifted their activity patterns towards the nighttime to avoid recreation. Similarly, two separate studies in California found that according to cameras placed along trails, mule deer did not decrease their use of an area as recreation levels increased, but mule deer did adjust their diel pattern to be more active at night and less active during the day (George and Crooks 2006, Reilly et al. 2017). Naidoo and Burton (2020) found that in British Columbia, Canada, mule deer did not adjust their weekly temporal trail-use patterns in response to recreation. However, they did find some evidence that at a finer temporal scale, mule deer did avoid trails in response to recreation, with the greatest lag in use between a recreationist and a deer occurring after motorized use or mountain biking. In contrast to Naidoo and Burton (2020), Nix et al. (2018) found that on their study site in Utah, mule deer decreased their activity on the weekends, especially in campgrounds, to reduce their temporal overlap with the higher recreation levels experienced on the weekend.

KEY POINTS

- Mule deer can **habituate somewhat to regular and predictable** (on-trail) recreation
- **Off-trail recreation** elicits a stronger response in mule deer than on-trail
- **Hikers with dogs**, even on-leash, provoke increased responses in mule deer
- Mule deer can **adjust their diel patterns** to reduce temporal overlap with humans

IMPLICATIONS FOR MULE DEER IN WASHINGTON



Mule deer habitat concentration areas.
Black-tailed deer range is largely west of the Cascades crest while
Rocky Mountain mule deer range east of the crest.

Source: WWHCWG 2010

Washington mule deer range is extensive and overlaps with all types of recreation from non-motorized activities in wilderness areas inhabited by migratory deer in summer, to year-round recreation exposure on lower-elevation public lands for non-migratory mule deer. A range-wide analysis of important mule deer areas and recreation overlap is needed to extrapolate specific zones of potential conflict.

For mule deer in Washington, high-intensity recreation that overlaps with important fawning, migration, and especially wintering areas is of particular concern. Managers wishing to eliminate potential negative impacts of recreation on deer should consider restricting both motorized and non-motorized recreation, since non-motorized recreation can also cause significant disturbance. Miller et al. (2001) suggests that because off-trail recreationists elicit stronger negative responses from deer, disturbance could be mitigated by restricting recreation exclusively to trails during sensitive times of year and in seasonally important habitat areas. Restricting dogs or requiring dogs to be leashed could further reduce recreation impacts in these areas. Additionally, in areas where nighttime recreation is increasing, mule deer may lose temporal refuge where 24-hour recreation access is allowed. In these areas, nocturnal closures to recreation could be considered, especially during sensitive times of year. Finally, spatial arrangement and number of trails should be considered in recreation management plans that overlap with mule deer habitat. For example, Price and Strombum (2014) suggest that building trails near areas with already high concentrations of human activity can decrease mule deer short-term responses to recreation (since these deer may be more habituated to humans). Consolidating trails can also reduce the human footprint and ensure refugia for deer fleeing from recreationists; however, managing trails is growing increasingly difficult for public land managers because of the expansion of unauthorized trail building. For example, in the Methow Valley, extensive unauthorized trail building occurs on Washington Department of Fish and Wildlife lands specifically created for Rocky Mountain mule deer habitat protection.

BLACK BEAR
(*URSUS AMERICANUS*)

Black bears (*Ursus americanus*) in Washington exist as a stable population estimated at 25,000-30,000 individuals that span the entire state with the exception of the Columbia Basin (Link et al. 2007). Black bears inhabit a wide variety of forested habitats, but will commonly use edges between differing habitats and open areas for feeding. As opportunistic omnivores, bears are also well known for their affinity to easy-to-access anthropogenic food sources such as trash, bird feeders, and compost piles. Their willingness to risk human interactions to access food emphasizes the need for management of recreational activities associated with anthropogenic food, such as camping and backpacking.

LITERATURE FINDINGS

In a 2012 study, Erb et al. deployed cameras at numerous sites along the Appalachian Trail and found that black bears used high-activity recreational trails significantly less than low-activity trails. A similar camera trap study of east coast black bears found that bears avoided the most heavily used trails, and that this effect was much stronger in areas where bears were hunted (Kays et al. 2017). Costello et al. (2013) investigated the movements, habitat use, activity, corridor crossings, and visibility to humans of GPS-collared black bears in Grand Teton National Park, Wyoming in response to a new recreational trail in the park's main throughway. The authors found that while black bears did not shift their home ranges or reduce the frequency at which they crossed the trail corridor, bears shifted their habitat selection patterns to steeper slopes and areas farther away from the trail corridor in response to increased recreational use. Black bears also modified how they crossed the corridor, selecting areas with greater vegetative cover for crossing and decreasing their daytime activity by approximately 35% near the trail corridor. Further, the proportion of trail corridor crossings at night time increased by 20-40%. While these spatial and temporal shifts in bear activity allowed black bears to continue occupying their territories, a notable direct consequence of these behavior shifts is that bears now cross the trail corridor and a parallel road at nighttime, increasing the risk of bear-vehicle collisions. This finding supports a study that found the

KEY POINTS

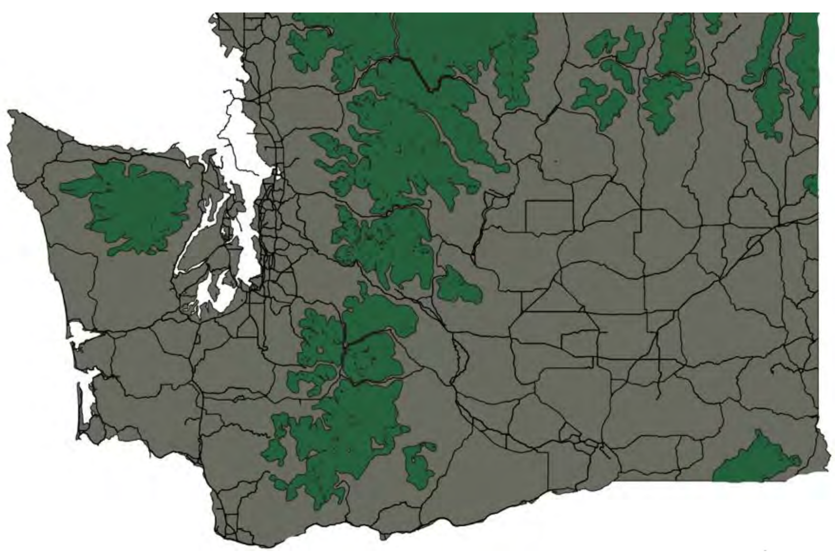
- Black bears can maintain territories with high recreational use, but will **alter both their behavior and movement patterns** to avoid encountering humans
- On trails with high recreational use, **black bears are both spatially and temporally displaced**, using trails less and shifting to more nocturnal activity patterns
- Recreation may have indirect effects on black bear population dynamics, including **increased mortality risk** from vehicle collisions and human-black bear conflict
- **Denning is a sensitive time for bears**; disturbance can cause abandonment of dens and cubs

density of recreation sites to be an important predictor of black bear vehicle-caused mortality (Wynn-Grant et al. 2018).

Temporal displacement of black bears in response to recreation was also revealed in a camera trap study along the wildland-urban interface in Colorado, where black bears were primarily active on game trails (where low to no recreation occurred) during daylight hours and more active at night on human recreation trails (Lewis et al. 2021). Similar temporal avoidance of black bears to human recreation was documented by Naidoo and Burton (2020), with avoidance highest for motorized ORV recreation and mountain biking.

Finally, hibernating black bears may abandon dens if disturbed, expending valuable energy reserves and in some cases, abandoning cubs. While no studies specifically investigated recreational impacts on black bear denning, Linnell et al. (2000) reviewed literature on the responses of bears to denning disturbance and found that bears were able to tolerate human activities at >1km, but that activities within 200m of a den sometimes led to abandonment, especially early in the denning season. Goodrich and Berger (1993) documented high sensitivity of black bears to disturbance, where approach of black bear dens for research purposes caused females to abandon den sites in 7 of 36 den approaches. In two of the den abandonment cases, females also abandoned their cubs. The authors suggest that recreational disturbance may have similar effects on denning bears and point out that in mountainous areas, skiers and denning black bears use similar site conditions; aspects with deeper snowpack and similar elevation and slope ranges. Findings of winter recreation impacts on brown bears [see *Grizzly Bears*] support this point.

IMPLICATIONS FOR BLACK BEARS IN WASHINGTON



Black bear habitat concentration areas

Source: WWHCWG 2010

Black bears can subsist in a wide variety of habitats and circumstances and as a result, bear range in Washington overlaps significantly with most types of recreation and across all seasons.

Black bears show high behavioral plasticity in response to recreation, avoiding encounters with humans by adapting both spatial and temporal patterns of habitat use. As a result, it is important to maintain both spatial and temporal refugia into which bears can shift their activity (Lewis et al. 2021). To minimize potential recreation impacts to Washington black bears, identifying areas of spatial refugia for protection from increased recreation is important, especially when land managers are evaluating proposals for future recreational development. Temporal refugia can be maintained by restricting use of recreational areas to daytime hours when human activity is already highest. To protect denning black bears, Goodrich and Berger (1993) recommend that managers use local black bear ecology to identify important denning areas where winter recreation should be restricted.

In addition, indirect effects of recreational activities are important considerations for black bear population maintenance. As Costello et al. (2013) noted, by shifting their activities to nighttime, black bears face increased risk of mortality as a result of vehicle collisions when crossing highway corridors at night. These potential indirect effects on black bears and other wildlife species with similar behavioral plasticity are of particular importance for populations residing near the wildland-urban interface.

Finally, black bear affinity for anthropogenic food resources can result in conflict with campers, backpackers, and hikers, where managers are often required to lethally remove individual problem bears (Wynn-Grant et al. 2018). As a result, it is important to consider that areas where bears and campers heavily overlap are both focal areas for human-bear conflicts and could act as population sinks, especially in Washington's National Parks. Implementation of measures to secure anthropogenic foods and garbage (e.g., at campgrounds and trailheads) could help to mitigate these effects.

CANADA LYNX
(*LYNX CANADENSIS*)

In Washington State, lynx populations are estimated at less than 100 individuals, where the only resident population is found on the east slope of the North Cascades (Stinson 2001). In addition, the Kettle River Range (hereafter, the Kettles) east of the Cascades is considered core lynx habitat and is currently undergoing a reintroduction effort. Lynx are adapted to living in high elevation sub-boreal forests with deep snow, where they rely on snowshoe hares for prey.

LITERATURE FINDINGS

The most extensive study of recreation effects on lynx took place in the Colorado Rockies from 2010-2013 and is described in two papers by Olson et al. (2018) and Squires et al. (2019). Olson et al. (2018) examined how motorized and non-motorized winter recreation might affect the spatial and temporal patterns of lynx, as well as their movement characteristics. Squires et al. (2019) examines how lynx habitat selection overlaps with the “habitat selection” of different types of winter recreation.

Olson et al. (2018) found that lynx (n=22) movement rates slowed in areas with greater snowmobiling and backcountry skiing, perhaps because they perceived a threat and responded by crouching and moving cautiously. However, their movement *pattern* did not change, indicating that while lynx may move more cautiously, they do not cease hunting activities or flee from the area. This result is similar to a finding from a 1998 study of European Lynx (*Lynx lynx*) in Norway (Sunde et al. 1998). Researchers approached bedded, radio-collared lynx and found that lynx fled at a median distance of 50 m. Flight distances were highly correlated with the amount of cover available, where lynx fled at longer distances in more open areas. The authors concluded that lynx tolerate close human approaches and that they can likely coexist with high human densities if sufficient forest and undisturbed habitats are available. However, it is important to consider that lynx may have a freeze response to threats, thus experiencing potentially costly physiological stress even if they do not flee.

In Colorado, backcountry recreation did not temporarily displace lynx as it occurred (Olson et al. 2018)**. Furthermore, there was only limited evidence that lynx spatially avoided dispersed recreation; for snowmobile assisted backcountry skiing, lynx in both study areas only avoided higher-use places. Lynx use was not affected in areas with low levels of snowmobile assisted backcountry skiing or snowmobile recreation, but as intensity of these recreation types increased, lynx use appeared to decrease. Lynx did not appear to avoid backcountry skiing, nordic skiing, or snowshoeing even where they occurred at higher intensities.

Interestingly, most lynx in the Colorado study were exposed to relatively low levels of

**In the Bohemian Forest Ecosystem (BFE), Belotti et al. (2012) found that when European lynx feeding sites were located closer to trails used for skiing, hiking, and biking, they traveled further during the day to find a resting site which could be energetically costly for lynx. A similar effect was not found for lynx with feeding sites near motorized roads. Additional evidence from Belotti et al. (2018) found that the probability of a lynx selecting a daytime resting location was negatively correlated with the estimated level (low, medium, or high) of non-motorized recreation within the surrounding 50x50 km area. While these results seem to contradict the findings of Olsen et al. 2018, behavioral and ecological differences between European lynx and Canada lynx could also account for the difference. Conversely, because quantitative levels of recreation were not obtained in the BFE studies we cannot compare them to those documented in the Olsen et al. (2018) study. It is possible that if BFE levels of recreation were higher than those observed in Colorado, Canada lynx may display a similar negative response to recreation if/where recreation levels reached those of the BFE studies.

recreation. However, the two individuals with the highest levels of snowmobiling, snowmobile assisted backcountry skiing, and backcountry skiing within their home ranges avoided all three of these recreation types where their intensity was high (Olson et al. 2018).

While some evidence showed that snowmobiling and snowmobile assisted backcountry skiing evoked a negative response in lynx, the authors also found that the probability of lynx use was always greatest in areas with higher forest cover and that this habitat effect generally had a stronger influence on lynx use than recreation (Olson et al. 2018). In addition, Squires et al. (2019) found that habitats used by snowmobilers, especially for off-trail use, were more open and thus less desirable to lynx, while skiing tended to occur more in the forested areas preferred by lynx. Congruent with these findings, a study in Riding Island National Park, Alberta found that the area with the highest probability of lynx use was also that nearest to the recreational hub for snowmobiling, snowshoeing, skiing, and ice fishing. These results indicate that, at least at the levels of recreation in Riding Island National Park (level not quantified or reported), lynx centered their movements according to habitat quality, not recreation use (Montgomery et al. 2014). In the case of heli-skiing, Squires et al. (2019) did not have a large enough sample size for a statistical analysis but anecdotally noted that the areas used by heli-skiers also tended to be more open and thus less valuable to lynx.

Olson et al. (2018) found little evidence for a temporal avoidance of recreationists: the proportion of time lynx spent active during the day and night were similar. However, there was some indication that at increased levels of recreation some lynx spent less time active during the day and more time active at night.

Olson et al. (2018) also looked at the response of six collared lynx living adjacent to a developed ski area for a total of nine lynx-years. Eight of the lynx-years demonstrated avoidance of the ski areas with fewer locations inside the ski area boundaries than expected. Furthermore, when lynx did enter the ski area boundary, they temporally avoided recreationists by entering more often at nighttime, on weekends, or during the off-season, demonstrating some level of temporal displacement.

Another extensive area of study relating to lynx and recreation investigates how packed snowmobile trails might increase overlap and thus competition for prey between lynx and coyotes. Compared to other mesocarnivores such as coyotes, the large feet and light body weight of lynx allow them to float atop deep snow more efficiently. This difference in ability to survive in deep snow environments creates a seasonal, spatial separation between lynx and coyotes, potentially decreasing wintertime competition for snowshoe hares (Buskirk et al. 2000). If packed snowmobile trails allow coyote access to deep snow areas year-round, biologists hypothesize they may consume more snowshoe hares and thus negatively impact lynx populations. Three studies looked at whether snowmobile trails increase coyote use of deep snow environments; however, mixed results indicate that results from one region may not translate to other regions, perhaps due to differences between snowpack characteristics and their effect on coyote movement.

Bunnell et al. (2006) examined whether snowmobile trails facilitated coyote use of deep snow areas in Utah where lynx historically ranged but are no longer present. They report that 90% of the coyote tracks observed were within 350 m of snowmobile trails and that coyotes used trails extensively. However, due to study design flaws (e.g., confounding variables), it is our recommendation that these results be regarded only as weak evidence for coyotes using snowmobile trails to access deep snow environments.

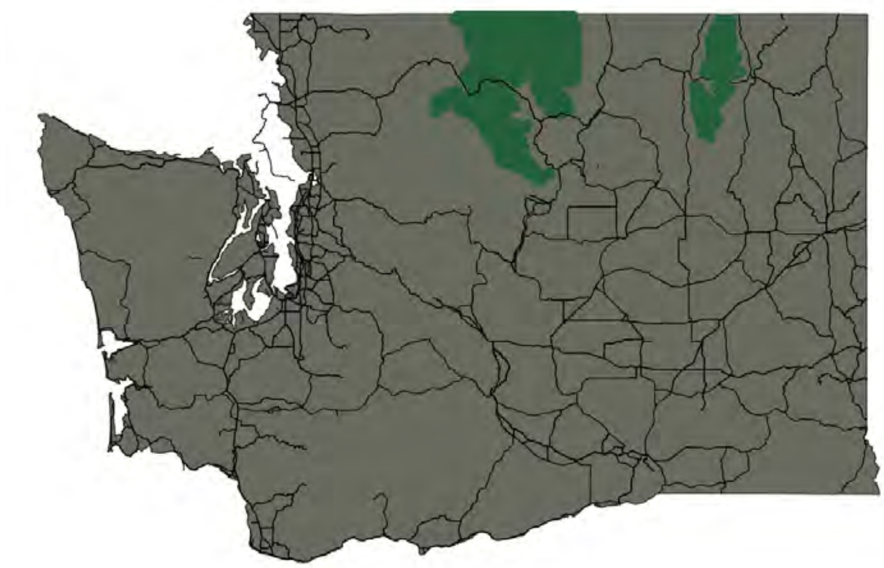
A robust study conducted in Montana by Kolbe et al. (2007) examined the effects of snowmobile trails on coyote movements in deep snow environments and concluded that while coyotes remained in lynx habitat throughout winter, it was unlikely that snowmobile trails were facilitating this use. Specifically, Kolbe et al. (2007) found that although coyotes remained in lynx habitat throughout the winter and used snowmobile trails more than randomly expected, coyotes did not prefer to use compacted trails while moving near them, nor did they move closer to compacted trails even as the snowpack became deeper and less supportive. In addition, coyotes used compacted snowmobile trails at the same rate that they used *un*compacted forest roads, indicating that they may be selecting for linear corridors regardless of snow compaction. Furthermore, this study found that despite coyote's year-round use of lynx habitat, snowshoe hares were a very small portion of their winter diet. Thus, the authors concluded that compacted snowmobile trails are unlikely to be affecting coyote movements or increasing competition with lynx (Kolbe et al. 2007)

Conversely, Dowd et al. (2014) performed a similar study to Kolbe et al. (2007) in Wyoming and found compacted snowmobile trails *did* influence coyote movements in lynx range. Researchers followed coyote trails and reported that although coyotes only used snowmobile trails 34.5% of the distance traveled, coyotes used snowmobile trails twice as often and traveled three times farther on snowmobile trails than randomly expected. Off-trail coyote travel stayed significantly closer to snowmobile trails than expected. Furthermore, as snow conditions became deeper and less supportive in the middle of winter, coyotes used snowmobile trails more, presumably because they offered easier, more efficient travel. The authors suspect that the contradictory results between their Wyoming study and Kolbe et al.'s Montana study (2007) were likely due to differing snow conditions. The drier, less supportive snow conditions found in Wyoming may increase the value of compacted snowmobile trails to coyotes whereas the more supportive snow conditions in Montana allow coyotes to easily travel off-trail (Dowd et al. 2014).

KEY POINTS

- **Low and moderate levels** of dispersed recreation do not appear to elicit a strong negative response in lynx
- **Higher intensities** of dispersed and developed recreation can cause avoidance in lynx
- Lynx avoid **developed ski areas** especially when ski hills are at their busiest
- There is **likely a threshold at which recreation intensity is too high** for lynx to coexist with
- Depending on snowpack density, **snowmobile trails may facilitate coyote use of lynx habitat** in winter which could increase competition for snowshoe hares

IMPLICATIONS FOR LYNX IN WASHINGTON



Lynx habitat concentration areas

Sources: North Cascades (USFWS Federal Register 70 FR 54781), Kettles (WWHCWG 2010)

Non-motorized recreation including hiking, mountain biking, horseback riding, and dog friendly trails are found throughout Washington lynx habitat, although mountain biking is not allowed in Wilderness areas of their range. ORV use is limited on USFS portions of their range but on the Loomis State Forest, extensive road systems are open to ORV use.

In winter, groomed and ungroomed nordic ski trails and a small developed ski-resort overlap with lynx habitat near Loup Loup pass, although this is currently a small area of fringe lynx habitat. Heli-skiing occurs in lynx habitat from Mazama north along the WA-20 corridor to Beebe Mountain, and from there northwest to the Pasayten Wilderness border. Heli-skiing is also popular in the Blackpine Basin, northward along the Pasayten Wilderness border, and in the Twisp River drainage east of Little Bridge Creek. In the Kettles, two formal but ungroomed ski areas overlap core lynx range and stretch mostly along the Kettle crest. At high elevations in the Methow Valley, snowmobiling is popular with a significant number of groomed snowmobile routes west of the Chewuch River on USFS land, as well as Blackpine Basin, Harts Pass, WA-20, the Twisp River drainage, and the Chelan-Sawtooth Mountains; snowmobiles are allowed off-trail in all of these areas. Backcountry skiing is also a favorite activity along the WA-20 corridor in the North Cascades when the road closes to vehicular traffic but is open to snowmobiles. In the Kettles, there is one groomed snowmobile route along the north end of the Kettle Crest Trail.

Findings by Olson et al. (2018) and Squires et al. (2019) provide insight regarding lynx and recreation overlap applicable to Washington. Intensity level of winter recreation is an important factor: lynx in these studies showed little response to low and medium levels of dispersed, backcountry recreation. Thus, the authors caution that restrictions (e.g., trail closures) in areas with low to medium recreation levels are unlikely to produce lynx conservation benefits. However, at high levels of recreation, lynx in Colorado did show some negative response and the authors acknowledge that restricting winter activities in areas of high-intensity recreation could be considered. Additionally, lynx in Colorado avoided a ski resort as an area of developed, very high intensity recreation. Development of ski resorts in Washington could cause similar fragmentation and loss of habitat for lynx and should thus be carefully considered to minimize potential impacts to lynx.

Recreation intensity is a difficult parameter to estimate and, to our knowledge, no quantitative assessment of winter recreation intensity is currently available for Washington lynx range. Given the apparent importance of recreation intensity to the ability of lynx to coexist with winter recreation, we recommend that recreation levels be assessed in popular areas that overlap with core lynx habitat. Areas where winter recreation levels reach the high level reported by Olson et al. (2018) could act as targeted areas to monitor for continued lynx occupancy or for implementing recreation management actions, such as visitor limitations. High levels of recreation quantified by Olson et al. (2018) were as follows: 1) Backcountry skiing levels at approximately 66 recreation tracks/km2; 2) Snowmobile assisted backcountry skiing equivalent to approximately 232 tracks/km2; 3) Snowmobile use at approximately 188 tracks/km2; and 4) Nordic skiing/snowshoeing at approximately 115 tracks/km2.

Studies exploring compacted snowmobile trails and coyote movements indicate that in areas and periods of winter with a deep, less supportive snow column, compacted snowmobile trails may be important for coyotes' ability to remain year-round in lynx habitat (Dowd et al. 2014). Conversely, in areas and periods of winter with a more supportive snow column, snowmobile trails may not significantly facilitate coyote movements (Kolbe et al. 2007). However, even if compacted snowmobile trails facilitate coyote access to lynx habitat in Washington, it is unknown whether greater coyote access results in increased coyote-lynx competition for prey. Kolbe et al.'s (2007) results suggest snowshoe hares were a small component of coyote winter diet; however, whether this is the case in Washington lynx range remains unknown. To reduce the potential risk of competition for prey between coyotes and lynx, limiting the spatial extent of snowmobile trail networks in lynx range could be considered, especially in important hunting habitat.

GRIZZLY BEAR
(*URSUS ARCTOS*)

Prior to their expiration in the mid-1900s, grizzly bears (*Ursus arctos*) occurred throughout Washington; however, the grizzly bear population is currently limited to a small population in the Selkirk Mountain Range in the northeast corner of the state. Washington contains two federally designated Grizzly Bear Recovery Zones; the Selkirk Recovery Zone (SRZ) and North Cascades Recovery Zone (NCRZ; USFWS). The SRZ population is thought to be increasing based on the most recent surveys, although human-caused mortality and extensive motorized access into the core of the recovery zone continue to threaten the full recovery of bears to the area (Lewis 2019). Although the NCRZ contains ample high-quality habitat for bears, natural recolonization of the area has thus far been unsuccessful and bears have not been documented in the area recently. Most recent efforts to actively restore grizzly bears to the NCRZ were terminated by the federal government in summer of 2020.

LITERATURE FINDINGS

Our search yielded a relatively large number of studies on grizzly bears and recreation effects, including a comprehensive review and 8 additional studies. Note that black bear-recreation literature could be used to supplement grizzly bear findings, but we caution conservation practitioners to consider behavioral differences between these two ursid species when extrapolating findings. The review by Fortin et al. (2016) included 46 papers on grizzly bear-recreation dynamics, including many of the papers revealed in our search. The review investigated a wide variety of recreational activities and found potential negative effects of recreation on grizzly bears for bear-viewing (n=18), hiking (n=11), angling (n=10), camping (n=4), non-motorized winter recreation (n=3), motorized winter recreation (n=1), mountain climbing (n=1), and ATV (n=1) activities. Fortin et al. included studies conducted on both European and North American brown bear populations, and established that both spatial and temporal displacement were grizzly bear's most common response to recreational activities.

Fortin et al. found several studies that indicated brown bears flee when directly approached by hikers at distances from 100-400 m, but could tolerate humans passing tangentially at distances <100 m. Flight distance was largely dictated by a bear's activity state at the time of encounter, where active bears fled greater distances than inactive bears. Habitat was also an important predictor of flight distance, where bears fled greater distances in open than closed habitats, and bears increased their selection of closed habitats in areas frequented by hikers (Fortin et al. 2016).

Temporal shifts in brown bear activity were also documented across numerous studies; bear-viewing, angling, hiking, and camping all caused bears to shift from diurnal activity to crepuscular or nocturnal activity patterns (Fortin et al. 2016). A more recent study by Oberosler et al (2020) found the same pattern in the Italian Alps, where brown bear activity was concentrated at night time and crepuscular hours while human recreation occurred during day time hours. Similarly, Cristescu et al. (2013) found that grizzly bears in Alberta shifted to selecting bed sites during the day in areas with high levels of recreational activity in contrast to more night time resting in areas with minimal recreational use.

In a camera trap study investigating grizzly bear use of trails in response to recreation in British Columbia, bears decreased trail use in response to mountain bikers but not hikers or horseback riders, suggesting that wildlife might perceive the faster speeds of mountain bikes differently than other non-motorized forms of recreation (Naidoo and Burton 2020). Indeed, Naidoo and Burton found that grizzly bears showed the strongest avoidance of mountain bikes, and were followed closely only by motorized recreation. Oberosler et al. (2017 and 2020) used camera traps to document that brown bears in the Italian Alps decreased use and frequency of use of trails in response to motorized traffic. Brown bears increased frequency of use on pedestrian trails; however, this was mediated by pedestrian passage rate, where bears used trails less frequently when human passage rate was high.

Similarly, a camera trap study in Alberta found some evidence that grizzly bears decreased use of trails at sites where summer motorized use was present (Ladle et al. 2018). Expanding on this camera trap study, the same authors used a larger dataset to investigate grizzly bear movements in response to recreation and found that solitary male and female bears avoided trails with a high-probability of motorized recreation use (Ladle et al. 2019). Furthermore, female grizzly bears avoided all trails, irrespective of recreation type (Ladle et al. 2019). The same pattern was found for movement rates, where all bears increased movement rates when near trails with a high probability of motorized recreation and females with cubs increased movement rates by a factor of three when recreation intensity was high compared to low. Interestingly, solitary male and female bears increased selection of non-motorized trails when probability of recreational use was high as opposed to low. While movement rates did not increase as much as they did in response to motorized recreation, solitary bears did increase movement rates on trails with a high-probability of recreation.

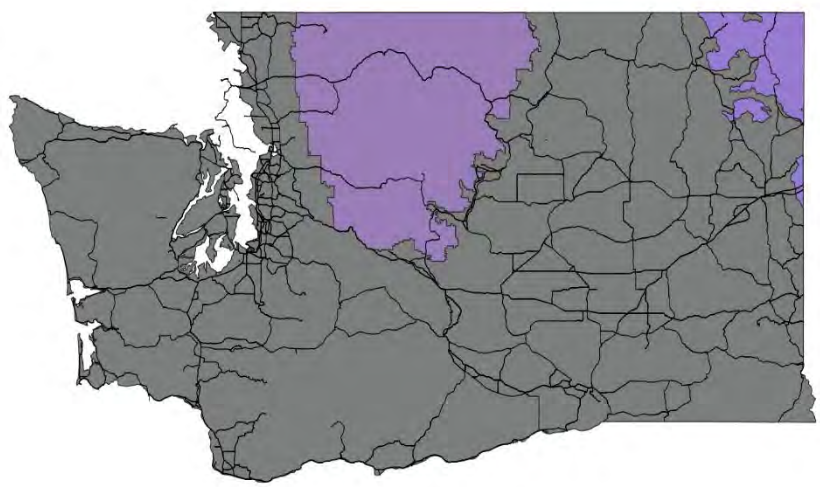
Fortin et al. found one study that documented brown bear den abandonment as a result of motorized recreation, and our search revealed two additional studies out of Alaska that cited negative effects of winter recreation on grizzly bear den selection (Goldstein et al. 2010, Crupi et al. 2020). Goldstein et al. (2010) found that grizzly bears select den sites on steep slopes far from roads (average distance = 14 km), high-use trails (average distance = 8.7 km), and low-use trails (average distance = 7.9 km). The study also documented the amount of high, medium, and low-quality denning habitat that overlapped with both motorized and non-motorized recreation. Interestingly, while snowmobile use occurred over 10 times more terrain than

KEY POINTS

- Grizzly bear displacement is of greatest concern during periods of **hyperphagia and denning**
- **Summer motorized recreation** has consistently strong, negative effects on grizzly bears
- Grizzly bears may shift activity to more **nocturnal behavior** and avoid areas of high human activity in response to recreation
- **Backcountry skiing and heli-skiing** activities often overlap with prime bear denning habitat and can cause bears to abandon den sites; consequences are greatest for reproductive female bears

non-motorized recreation (skiing and snowshoeing), non-motorized recreation occurred much more frequently in high-quality grizzly bear denning habitat. Furthermore, 54% of the area where non-motorized recreation overlapped with high-quality denning habitat was in areas of high intensity human use, whereas motorized recreation in high-quality denning habitat was spread evenly across areas of high, medium, and low intensity human use. In particular, female grizzly bears denned on steep, isolated slopes most likely to be used by backcountry skiers. Goldstein et al. caution about increased impacts of non-motorized winter recreation when assisted by motorized vehicles (snowmobile, cat skiing, and heli-skiing) or other backcountry facilities that will further disperse these activities. Curpi et al. (2020) specifically assessed heli-skiing impacts on grizzly bear den selection and found fewer dens than expected in approved heli-skiing zones that overlapped high-quality denning habitat, where 74% and 26% of dens were found outside and inside of the heli-skiing zone, respectively. Most dens found within the heli-skiing zone occurred at the edges of these areas, with two-thirds of the den sites found within 1 km of the heli-ski zone boundary and 50% in areas of low-intensity heli-skiing use. Finally, while anecdotal, Curpi et al. documented one instance of a helicopter coming within 400-1000 m of a den site; the female grizzly bear occupying this den site abandoned the den, did not re-den, and did not return to the den site.

IMPLICATIONS FOR GRIZZLY BEARS IN WASHINGTON



Grizzly bear recovery zones

Sources: Western: North Cascades Recovery Zone (NCRZ); Interagency Grizzly Bear Committee. Eastern: Selkirk Recovery Zone (SRZ); USFWS Federal Register 41 FR 48757 48759

In the SRZ grizzly bears overlap with extensive areas of summer and winter motorized recreation, including ORV and snowmobile use. Groomed snowmobile trails without off-road restrictions cover much of the Washington portion of the SRZ, with the exception of the most northern extent of the area. The southern half of the Washington SRZ contains relatively high densities of ORV-accessible trails. Were grizzly bears to recolonize or be restored to the NCRZ, summer non-motorized recreation in this region, including hiking, mountain biking, and mountaineering, would cause similar spatial and temporal displacement concerns and increase the potential for human-bear interactions. The extensive network of hiking trails and campgrounds throughout the NCRZ would be focal points for interactions. In addition, there are numerous popular backcountry skiing destinations within the NCRZ and this area hosts the sole heli-skiing operation in the state. In areas accessible to both motorized and non-motorized winter recreation, especially up WA-20 in the Washington Pass area, the Stevens Pass area, and in the vicinity of Mt Baker, these activities would likely overlap with areas used by grizzly bears for denning in the NCRZ.

The number of grizzly bears in Washington is currently limited to a very small population in the northeast corner of the state, for which the most recent WDFW Periodic Status Review explicitly identified motorized access into SRZ habitat as one of two primary barriers to the population's continued growth. Motorized access in the status review includes both recreational and other motorized travel and our literature review supports this notion; we found extensive literature documenting spatial and temporal displacement of grizzly bears by motorized recreation. Reducing road densities through wildland areas in the SRZ by decommissioning select unmaintained roads and limiting the construction of new roads could help support bear populations in this area. Areas with road densities <0.6 km/km2 are recommended for grizzly bears in Washington (WA Periodic Status Review 2019). Summer non-motorized recreation, especially mountain biking, hiking, and bear viewing can also displace grizzly bears. This is particularly important both in areas of high natural food abundance, and during hyperphagia (late-summer to fall), the critical period in which bears store energy for their winter torpor. Non-motorized trails should be planned to avoid areas of high natural food abundance where possible.

Winter recreation impacts on grizzly bear denning activities are of concern as bears will often select areas away from human activity and on steep slopes at moderate alpine elevations that ensure stable and persistent snow coverage to den. Both motorized and non-motorized recreation can potentially cause bears to abandon their dens, which could have both severe reproductive and energetic costs. Thus, areas of overlap between winter recreation and high-quality denning habitat should be identified in the SRZ and the NCRZ and flagged for recreation management to mitigate possible den abandonment. The low density of dens on the landscape means that direct encounters of recreationists with den sites is likely low; however, noise is a primary concern for denning (Goldstein et al. 2010) and more research is needed to better understand the winter soundscapes that motorized recreation create (see also, Wolverines). To mitigate this concern, Crupi et al. (2020) suggest a 1.5 km buffer for heliskiing zones from prime denning habitat and advise that operations maintain flight altitudes >500 m over denning habitat. Finally, while motorized recreation may have broad impacts through their soundscapes, it is important to note that non-motorized recreation, specifically backcountry skiing, had the largest overlap with high-quality denning habitat. Therefore, it is important to limit motor-assisted recreation access in high-quality denning areas for non-motorized recreational users (Goldestein et al. 2010).

Fortin et al. 2016 analyzed data from their literature review and the opinions of 12 bear brown bear experts to assess impacts on bears and provide management recommendations. Their results suggest that displacement can affect individual bear health, reproduction, and survival, mainly as a result of decreased nutritional intake and increased energetic costs, especially during hyperphagia. However, the authors note that there are no studies of the impacts of recreation on bear energetics and this is an important area for future research. In addition, Fortin et al. used expert opinions to identify the top three most important management recommendations for grizzly bear-recreation coexistence. These include:

1) Public education on what to do when encountering a bear, trainings on how to appropriately use bear deterrents, and guidelines on where bears are likely to occur based on natural food availability.

2) Implementation of measures to secure anthropogenic foods and garbage (e.g., at campgrounds and trailheads) as this is the primary cause of human-bear conflicts in North America

3) Restriction of further road development to minimize road density in critical habitat and the use of permanent, seasonal, or daily closures in prime bear habitat for feeding and travel corridors.

MOUNTAIN LION

(*PUMA CONCOLOR*)

Mountain lion (*Puma concolor;* also known as Puma, Cougar) communities in the western United States and Canada are widespread. In Washington state they maintain a healthy population, with an estimated 1,900-2,100 individuals (Western Wildlife Outreach 2018). Mountain lions are largely nocturnal, ambush hunters and prefer habitats with heavy cover such as dense forest, rocky outcroppings, and steep canyons which occur widely throughout the state and support a variety of recreation opportunities.

LITERATURE FINDINGS

Literature specific to recreation impacts on mountain lions is sparse and largely examines recreation areas adjacent to high levels of urban and exurban development. Studies vary from examining the effects of ORV use and non-motorized trail use to recreation with dogs. Changes in abundance, spatial displacement, and behavioral shifts were most commonly considered in the research.

Several studies found that mountain lions change their diel patterns near trails by shifting early morning activities to nighttime (Sweanor et al. 2008, Wang et al. 2015, Nickel et al. 2020, Lewis et al. 2021). In contrast, mountain lions in Utah did not temporally shift their trail use in response to recreation intensity since their nocturnality sufficiently eliminated overlap with human activity (Nix et al. 2018). Taken together, these results suggest that under certain circumstances mountain lions can use temporal changes to avoid human encounters without the need to relocate to entirely new habitats, but the necessity for this shift may be dependent on the intensity of recreation and the availability of alternative high-quality habitat in a given area.

In addition to temporal avoidance of recreation, some studies have found that mountain lions spatially avoid recreation. Lewis et al. (2021) found mountain lion occupancy and habitat use on Colorado’s Front Range decreased as the intensity of human activity increased. Similarly, mountain lions in Alberta and Saskatchewan shifted to using habitats farther from trails during peak visitor months, although they maintained some trail use throughout the year (Morrison et al. 2014). Finally, mountain lion abundance in Northern California was higher in areas that prohibited recreation but lower in areas that allowed recreation, where mountain lion abundance in these areas continued to decrease as recreation intensity increased (Reed and Merenlender

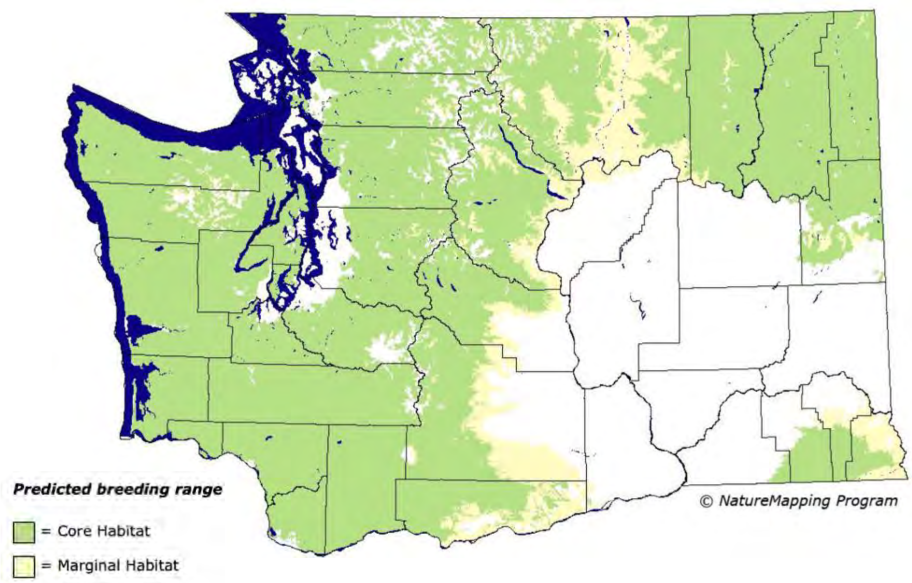
KEY POINTS

- Mountain lions are displaced by areas that allow recreation, and **abundance decreases as recreation increases**
- Nocturnality helps mountain lions **avoid recreation temporally without shifting spatially**, but lions will still alter diel patterns to consolidate morning and evening activities to nighttime
- Although it is unclear if dogs play a role in mountain lion abundance, **areas where dogs are allowed may see higher recreation use** and therefore decrease mountain lion use of those areas

2011). This study also examined the effect of domestic dogs on the abundance of multiple carnivores and found that the presence of recreation decreased mountain lion abundance, regardless of whether dogs were allowed or prohibited. However, areas that allowed recreation *and* dogs had 60% more visitors than those that allowed recreation *but prohibited* dogs, suggesting dog restrictions may decrease overall recreational use of an area.

Only one study focused on motorized recreation. ORV use on trails in several protected areas in the Everglades region of Florida did not affect the distance that male Florida panthers (*Puma concolor coryi*) maintained from trails, but they were more likely to select areas that had no motorized trails or a lower density of trails (McCarthy and Fletcher 2015).

IMPLICATIONS FOR MOUNTAIN LIONS IN WASHINGTON



Mountain lion breeding range

Source: Nature Mapping accessed 2/15/2022

Mountain lion range is extensive in Washington, spanning two-thirds of the state and inhabiting a wide variety of habitats. This range overlaps with areas where many types and intensities of recreation occur, but it is unknown to what extent. A detailed analysis of mountain lion habitat and recreation overlap is needed to reveal areas where recreation may be impaction mountain lions.

The limited body of scientific knowledge about recreation and mountain lion interactions is concerning for management in a state with an abundance of both. Although several of the existing studies found important negative effects on mountain lion occupancy, habitat use, and abundance (Lewis et al. 2021, Morrison et al. 2014, and Reed and Merenlender 2011), these were all conducted in areas adjacent to high levels of urban and exurban development where mountain lions have limited access to alternative habitat. This further highlights the need for understanding the spatial overlap of mountain lion range with recreation in Washington, where vast parts of the state are rural or remote and may present different circumstances than those represented in the literature. In areas where high levels of recreation do overlap with high-quality mountain lion habitat, managers could consider limiting visitation and instating dusk to dawn trail closures (Sweanor et al. 2008) to mitigate possible negative impacts to lion space use and abundance. These recommendations, in addition to educational outreach about mountain lion ecology and their use of recreational trails (Morrison et al. 2014) are best management practices until more information can be gathered about mountain lion-recreation dynamics.

WOLF
(*CANIS LUPUS*)

Wolves first returned to Washington in 2008 after extirpation in the 1930s. The state has since seen steady increases in the wolf population, with colonizers coming from both British Columbia to the north and Idaho, Montana, and Oregon to the east. Like many predators, wolf populations are closely tied to prey populations, including deer, moose, and elk, and were historically found throughout the state. This wide-ranging, anthropophobic species typically avoids interactions with humans and as a result, its modern range is limited to less densely populated areas. Even in the more rural areas where wolves have begun to reestablish, their use of the landscape is typically restricted to more mountainous, remote regions, given the prevalence of human activity (primarily agricultural and ranching) in fertile valley bottoms and the high desert flatlands. Washington's wolf population has been growing by an average of 28% per year since 2008 and wolf packs can now be found throughout much of the northeast part of the state, with limited populations along the eastern slopes of the Cascades and the Umatilla National Forest in the southeast corner of the state, with the notable exception of limited, more recent activity of a single pack on the western slope of the Cascades (Washington Department of Fish and Wildlife - Wolves, n.d.).

LITERATURE FINDINGS

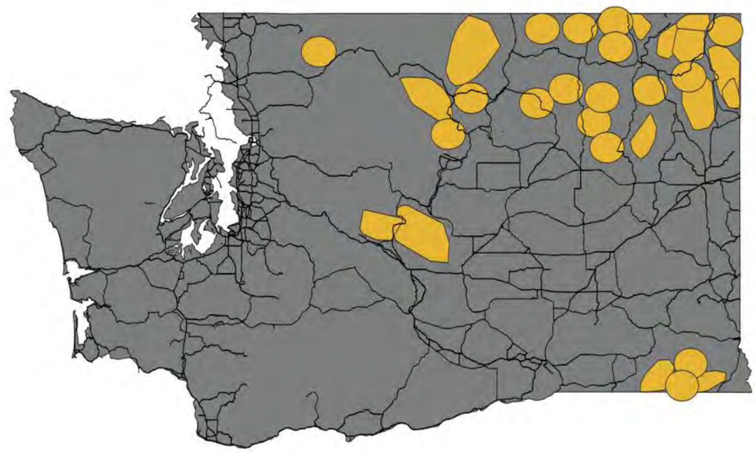
Multiple studies have documented wolf sensitivity to roads, where increasing road densities can displace wolves, impede their ability to disperse, and influence wolf pack locations (see Gaines et al. 2003). While road related factors have strong effects on wolves, the literature documenting wolf response to summer recreation trails is mixed. In a large-scale camera trap study by Naidoo and Burton (2020) that captured both wolves and human recreationists on trails in the mountains of British Columbia, researchers sought to document both wolf displacement in response to human use and the frequency of wolf trail use in relation to recreation intensity. The study documented these responses for numerous wildlife species, and found that wildlife more broadly avoided motorized vehicles and mountain bikers than hikers and horseback riders; however, the study found no significant effects of any recreation types on wolf frequency of use or displacement. Using finer scale data from GPS-collared wolves and hourly human activity data, Rogala et al. (2011) revealed wolf avoidance of human activity at various buffer distances. This study, conducted in the mountains of British Columbia and Alberta, found wolves avoided areas within a 400 m buffer of trails in response to even low levels of human activity which could result in indirect habitat loss. Interestingly, this study also collected data on one of the wolves' primary prey in the area, elk, and found that between a 50-400 m buffer of trails, elk tolerated low levels of human activity, creating a slight refugia for the prey species. This refugia disintegrated once human activity increased beyond low levels (> 2 people/hr).

Other reported impacts of recreation on wolves include both indirect and modeled effects. Creel et al. (2002) measured physiological stress responses of wolves in response to snowmobile activity using cortisol levels in sampled wolf scats. The study measured wolf stress levels in two neighboring national parks, Voyageurs (Minnesota) and Isle Royale (Michigan), which are open and closed to snowmobile use, respectively. The study found that wolf stress levels were elevated on both a day-to-day and across-year basis in areas where wolves were exposed to snowmobile recreation. While the elevated stress levels measured cannot be directly linked to population-level impacts, science has established clear links between elevated stress levels and the suppression of both the immune and endocrine systems. Conversely, Creel et al. note that snowmobile tracks compact snow and could potentially counteract their negative physiological effects by providing wolves with more efficient travel pathways; although, this hypothesis has not been tested. Finally, Musiani et al. (2010) used simulated data derived from GPS-collared wolves in Alberta and British Columbia to model how increasing human activity may influence wolf space use and movements. Results from their modeling exercise noted that increasing human activity is likely to shrink wolf home ranges and increase human-wolf encounter rates. Increased human activity could also displace wolves from valley bottoms where prey, water, and cover resources are consolidated to areas with lower prey densities which may impact wolf survival.

KEY POINTS

- There is mixed, but limited evidence of recreational activity on wolves; both **neutral and negative** responses were documented
- Human activity causes wolves to avoid areas within a **400 m buffer** of trails
- Wolves are highly sensitive to increasing road densities
- **Additional research** is needed to understand how increasing trails densities impact wolf use

IMPLICATIONS FOR WOLVES IN WASHINGTON



Current wolf pack home ranges in Washington

Source: Washington Geospatial Open Data Portal accessed 6/1/2022

As wolves continue to recolonize Washington, their persistence and continued recovery are closely tied to prey availability and human activity. Nearly all of Washington's wolf packs have home ranges on public land, tribal lands, or private timber inholdings in the more mountainous and forested parts of the state. A notable exception here is wolves' absence from much of the North Cascades, and in particular areas to the west of the Cascade crest. The rugged, steep terrain of the North Cascades is not conducive to the requirements of ungulate populations that wolves require for survival. In addition, most of the gentler terrain to the west of the crest that supports both elk and black-tailed deer populations contains heavy human development, which appears to limit their willingness to use these areas.

Along the eastern slope of the Cascades, wolves are likely most strongly impacted by spring and summer non-motorized recreation, including hiking and mountain biking activities. Summer and winter motorized recreation may also impact wolves where networks of ORV and groomed snowmobile trails are abundant (e.g., the foothills between the Okanogan and Methow Valleys). In the northeast part of the state, wolves primarily overlap with motorized activity in all seasons, including snowmobile and ORV vehicles. In the southeast corner of the state, wolves may be impacted by lower intensities of both motorized and non-motorized recreation throughout all seasons.

The South Cascades, Olympic Peninsula, and western coastal regions of the state all contain additional habitat with robust prey populations; however, dispersal to these areas appears to be limited primarily by a lack of connectivity through more heavily populated areas. An important consideration here is how much recreation along the Stevens and Snoqualmie Pass corridors might limit wolf movement to the South Cascades. Both corridors see extensive year-round recreational use and may significantly impede wolves' abilities to disperse to these parts of the state. Wolves have been detected near Stevens Pass, and both the Teanaway and Naneum packs reside in the eastern Cascade foothills to the north of I-90 but further dispersal has thus far been limited. This is an important area for further research if wolves are to successfully recolonize the Southern Cascades and Northwest Coast recovery zone, and meet WDFW criteria to consider wolves fully recovered in the state of Washington (Wiles et al. 2011).

Studies of direct impacts of recreation on wolves are scarce and mixed; however, there is some evidence that it is important to maintain spatial refugia for wolves in areas with non-motorized recreation trails. Rogala et al. (2011) found that even at low levels of activity, wolves avoided areas within a 400 m buffer of trails, thus it may be advisable to construct compact trail networks to avoid fragmentation of important wolf habitat, such as areas with low road densities, high prey availability, and in close proximity to known den and rendezvous sites. Furthermore, recreation could indirectly impact wolf pack locations, impede continued dispersal, displace wolves, and fragment their range if associate road networks become too dense. Roads have been documented to both reduce wolf use and act as a barrier to dispersal (Jensen et al. 1986) in areas with an average road density >0.6 km/km2 (Gaines et al. 2003). As a result, areas with high road density that overlap with otherwise suitable Washington wolf habitat could be identified and targeted to both reduce road densities by decommissioning select unmaintained roads and limit the construction of new roads.

WOLVERINE
(*GULO GULO*)

Wolverines (*Gulo gulo*) are closely tied to persistent snowpack through the month of May for reproductive purposes, their dependence on carrion preserved in the snowpack, caching food, and avoidance of competitors (Heinemeyer et al. 2019). Of particular importance, female wolverines birth and raise kits in dens dug into the snowpack, protecting vulnerable young from both predation and cold temperatures. In Washington, wolverine habitat containing persistent spring snowpack is limited to the Cascade Mountain Range and possibly the Selkirk Mountains in the northeastern corner of the state. After extirpation from the state in the mid-1900's, wolverines are actively recolonizing Washington and are closely tied to the wolverine populations in southern British Columbia. Habitat loss, fragmentation, and climate change are all considered primary threats to wolverines in Washington (Washington Department of Fish and Wildlife - Wolverines, n.d.). Because wolverines occupy mountainous areas that are difficult to survey, exhibit wide ranging behavior, and generally occur at low densities, our understanding of wolverine's population trends across the state are limited.

LITERATURE FINDINGS

The importance of persistent spring snowpack for denning female wolverines has resulted in a strong focus on potential impacts of winter recreation on patterns of wolverine habitat use and selection. Although the literature on wolverines and recreation are limited to two papers, each of these studies investigated wolverine response to a variety of winter recreation activities across multiple study areas. Krebs et al. (2007) investigated the effects of heli-skiing, snowmobiling, and backcountry skiing by measuring selection by GPS collared wolverines in response to the proportion of each winter recreation use type at 3 different scales: landscape (7.6 km radius); meso (2.3 km radius); and fine (0.7 km radius). The study, conducted across two independent areas in British Columbia, used data from 39 wolverines to reveal negative effects of heli-skiing on male habitat use at the meso scale, and negative effects of heli-skiing and backcountry skiing on female wolverine habitat use at the landscape scale. For all models of wolverine habitat use, recreation factored more strongly in models of female habitat use than those of males, suggesting that females are more sensitive to recreational activities.

The findings of Krebs et al. were supported by a more recent study conducted by Heinemeyer et al. (2019) across four study areas and three states in the Rocky Mountains: Idaho, Wyoming, and Montana. The study was conducted over a 6-year period and used data from 39 animal-years to provide unique, relatively long-term insights into wolverine habitat use and selection. Heinemeyer et al. investigated the effects of backcountry skiing, snowmobiling, heli-skiing, cat-skiing, snowmobile accessed skiing, and ski resorts, tracking the intensity and distribution of recreational use using a combination of GPS tracking units distributed to volunteer recreationists, infra-red trail use counters, and aerial surveys on both high (weekend: Saturday and Sunday) and low (weekday: Tuesday and Wednesday) use days. Fix rate schedules for wolverine GPS collars were programmed to collect data at an increased rate during high and low use days, where data was used to model wolverine habitat selection and behavioral response in low, medium, and high-quality habitat.

Heinemeyer et al. found that models including winter recreation indicated both male and female wolverines responded negatively to increased levels of recreation within home ranges, where dispersed and off-road recreational activities elicited a stronger response than activities on roads and groomed trails. Among dispersed and off-road recreational activities, wolverines showed a stronger behavioral response to motorized recreation, indicating that behavioral avoidance of recreation in important high-to-medium quality wolverine habitat may result in indirect habitat loss if a large proportion of an individual's habitat is impacted by recreational use. Many of the resident animals in the Heinemeyer et al. study were able to withstand recreation to some degree, where the home ranges of some animals overlapped with areas of winter recreation by more than 40%. However, within these home ranges, wolverines appeared to avoid all forms of recreation, again with the strongest response to off-road motorized recreation. This avoidance degraded 14% and 10% of high-to-medium quality habitat for female and male wolverines, respectively. Conversely, wolverines showed only weak avoidance of linear features used for winter recreation, indicating that wolverines were not heavily impacted by these more concentrated areas of predictable human activity.

Although wolverines responded more strongly to motorized off road recreation, non-motorized dispersed recreation elicited similar responses. Both of these forms of recreation likely impacted wolverines the most due to the unpredictable nature of the activities. The notable difference across the study areas surveyed by Heinemeyer et al. was the footprint of motorized vs non-motorized recreation, where off-road motorized recreation both comprised the largest proportion of the recreational footprint across all study areas and occurred at the highest intensities. In contrast, while wolverines still responded strongly to non-motorized dispersed activity, the footprint of these activities affected less than 5% of an individual wolverine's home range on average.

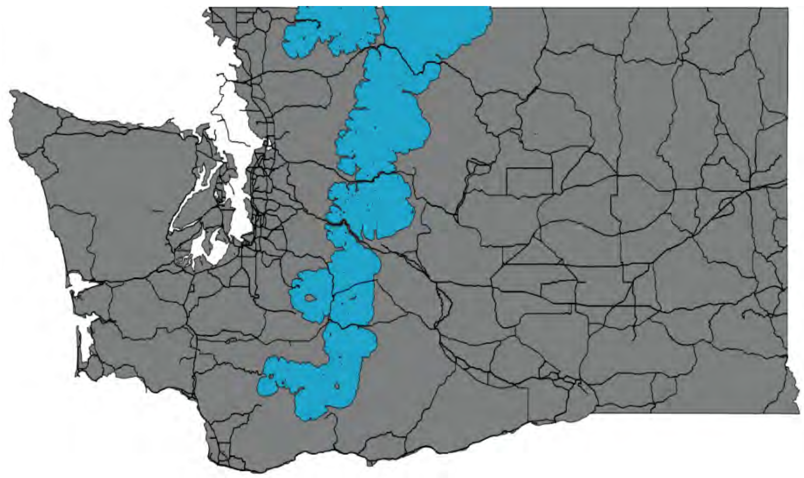
Similar to the findings of Krebs et al. 2007, Heinemeyer et al. found that while both male and female wolverines avoid recreation, females showed the strongest responses, and especially to off road motorized activities with increasing intensity. Furthermore, of the 10% and 14% medium-to-high-quality habitat degraded by winter recreation for males and females respectively, nearly 10% the female's degraded habitat was considered high-quality in contrast to 0.2% for male wolverines. In addition, data from this project suggest that denning female wolverines moved more frequently and at faster speeds when subjected to increasing intensities of recreational activity (Heinemeyer and Squires 2013). Furthermore, while no study has

KEY POINTS

- Wolverines are most affected by **dispersed and off-road activities**, such as snowmobiling and backcountry skiing
- **Reproductive females** are especially sensitive to disturbance
- The **relative footprint** of a given activity (motorized and non-motorized) is a key consideration for wolverines
- Wolverines are closely tied to **persistent spring snowpack** and are likely to face increases in habitat loss in the face of climate change

documented this effect, it has been suggested that wolverines are disturbed by both site-specific use and the noise produced by snowmobiles, which may cause denning females to abandon dens and reduce reproductive success (Switalski 2016).

IMPLICATIONS FOR WOLVERINES IN WASHINGTON



Wolverine habitat concentration areas

Source: WWHCWG 2010

Wolverines have been detected at camera trap stations and via community science observations throughout the Cascades, including many areas frequented by both summer and winter recreationists. These areas include terrain surrounding popular recreation hubs in the Mount Baker Wilderness, the North Cascades, the I-90 corridor at Snoqualmie Pass, Mount Rainier National Park, and the Mount Adams area (Williams and Moskowitz 2020). Summer recreation impacts to wolverines in the Cascades are likely concentrated towards non-motorized activities including hiking and mountaineering. In the winter, wolverines may be impacted by both motorized and non-motorized activities, including backcountry skiing, snowmobiling, and heli-skiing.

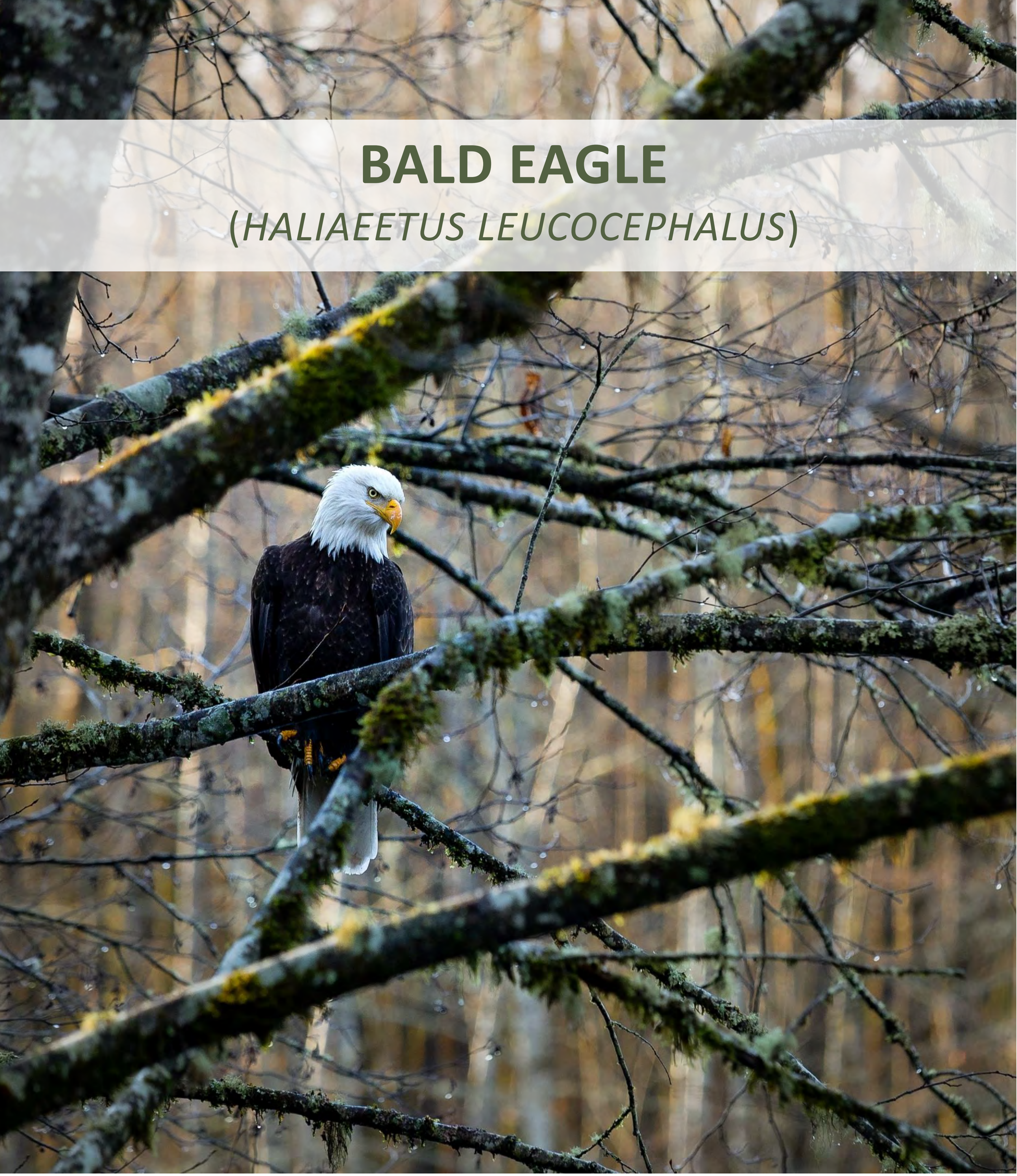
Wolverine reliance on persistent spring snowpack for survival and reproduction implies that it will be particularly vulnerable to the effects of climate change. Similarly, winter recreation will face many of these same challenges in the alpine as both the extent and depth of snowpacks across the Cascade Range decrease with shortening snow seasons. This loss of snowpack is predicted to reduce wolverine habitat to 67% of that currently available by the year 2059 (McKelvey et al. 2011), further concentrating the areas where wolverines and winter recreational activities overlap. These effects will likely be greatest for reproductive female wolverines who will also experience increasing temporal overlap with winter recreation during spring months (February-May) that are both most important for denning and provide the most consistent and stable snowpack to recreationists. Seasonal closures of high-quality wolverine denning habitat during this period, particularly in less accessible areas or those with known den sites, could help to limit disturbance and support reproduction.

As a wide-ranging species, Heinemeyer et al.'s work highlights that wolverines can tolerate winter recreation in as much as 40% of their home range; however, because habitat quality is degraded by unpredictable off-road and dispersed recreation, measures should be taken to limit off-trail travel to designated areas. Motorized recreation in particular can leave a significant footprint of use across the landscape, so careful consideration should be taken before opening additional groomed access points and heli-skiing areas. At present, both North Cascades and Mount Rainier National Parks protect large swaths of important wolverine habitat in Washington's Cascades, and the partial closure of WA-20 through the North Cascades limits winter recreation in this area, creating the largest contiguous swath of minimally disturbed winter habitat for wolverines. Limiting any further winter motorized access to these protected areas could help to preserve spatial refugia; large areas of habitat that can be protected from both frequent and unpredictable recreation are critical for wolverine persistence in Washington. Furthermore, we have limited understanding about the extent to which wolverines are impacted by noise associated with motorized travel and this is an important area of future research. In the interim, tools such as SPreAD-GIS, the Integrated Noise Model, and the Noise Simulation Model can be used to model the sound shed affected by motorized winter vehicles.

Finally, while recreational impacts to wolverines in Washington are greatest during the winter, our understanding of potential summer recreation impacts to wolverines is limited. With the increasing popularity of alpine activities such as mountaineering and wolverine's known aversion to unpredictable winter recreation, understanding the effects of dispersed, off-trail summer travel on wolverines would improve our understanding of broad-scale recreational impacts on wolverines.

BALD EAGLE

(*HALIAEETUS LEUCOCEPHALUS*)



Although communities throughout the United States are now stable, the bald eagle (*Haliaeetus leucocephalus*) has undergone decades of population fluctuation. In Washington, this species can now be found in all parts of the state, with a large concentration of its breeding population inhabiting the coastal waterways west of the Cascade crest and in the northeast. However, locations with close proximity to bodies of water and reliable food sources are suitable habitat choices for bald eagles across the state, and these requirements become especially important during the breeding season.

LITERATURE FINDINGS

The scope of this literature search focused only on the effects of terrestrial recreation on bald eagles, but it should be noted that additional research has been conducted on the impacts of aquatic recreation and these results should also be considered for management of recreation impacts on bald eagles. Most bald eagle studies were conducted in the western contiguous United States, with additional studies in Alaska and the Midwest. Behavioral changes and nest success were the primary responses measured in the literature, where the effects of camping and pedestrian approach were studied in both observational and experimental capacities. However, some of the literature also examined impacts of motorized and aircraft activities, results of which will be included here where appropriate.

Bald eagles are most sensitive during nesting season (March-July) and adults are easily disturbed during this time. In Washington's Puget Sound, where eagles are routinely exposed to disturbance from adjacent urban activity, the frequency with which eagles flushed from their nest increased as an approaching observer's distance from the nest decreased (Watson 2004). Fraser et al. (1985) obtained analogous results in a similar study, where nesting eagles flushed more often as pedestrians moved closer to the nest. Grubb and King (1991) argue that the distance of a recreationist to the nest is the most important factor in eagle flushing response. In addition, camping activities within shorter distances of bald eagle nests elicited increased flushing behavior (Steidl and Anthony 2000). A buffer zone of at least 500 m decreased the frequency with which eagles responded to disturbance (Fraser et al. 1985, Grubb and King 1991, Steidl and Anthony 2000, Watson 2004), and a secondary buffer of 1,200 m is effective at reducing the impacts of louder, longer and more distant disturbances (e.g., motorized and aircraft activities; Grubb and King 1991). Although flushing distance is the most widely studied behavioral response, eagles also significantly reduced nest maintenance, feeding, perching, preening and sleeping when recreational activities occurred at close distances (100 m). These changes have ramifications for nest success and, if not managed, could potentially lead to population decline (Steidl and Anthony 2000).

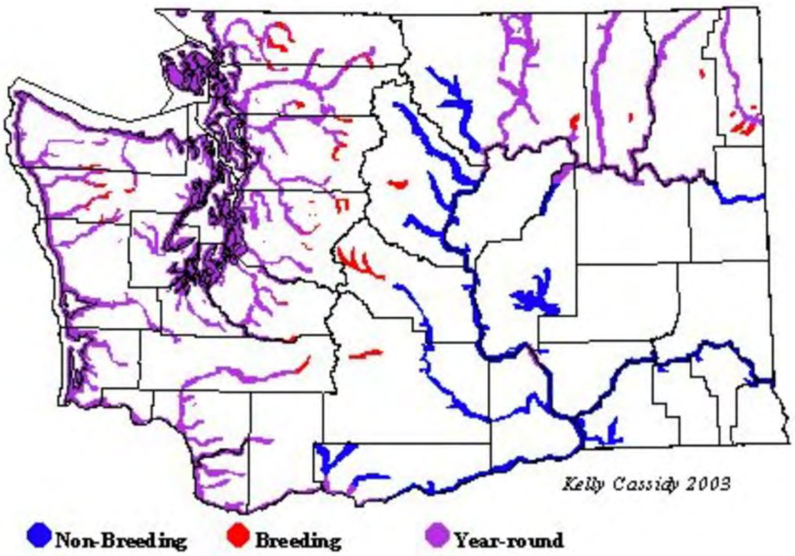
While increasing the distance of disturbance events from eagle nests is a simple management strategy, the buffer zone size must be adjusted according to habitat characteristics. Nest height and visual screening (e.g., vegetation density) influence effective buffer distances as eagles respond less when they are out of sight of recreationists (Stalmaster and Newman 1978, Grubb and King 1991). Similarly, outside of the breeding season, adult eagles rely on vegetative cover for protection from disturbance, and will flush at farther distances when in plain view or at the same height as the disturbance (Stalmaster and Newman 1978). On the Nooksack river in Washington, experimental approaches to bald eagles feeding on salmon carcasses (which primarily took place in the open) caused eagles to leave the area for the remainder of the day. On days when eagles were undisturbed, they fed longer and ingested more than on days with disturbance treatments (Skagen et al. 1991). Eagles also shifted their activity spatially to avoid areas of high recreation, even when the trade-off resulted in limited access to high-quality habitat (Stalmaster and Newman 1978). These authors also suggest a spatial buffer between human activity and eagles of 75 m-250 m, with the largest buffers in high-quality habitat and feeding areas.

There is weak evidence that eagles habituate to human activity, where various behaviors normalized after increased frequency of exposure to recreational disturbance; however, eagles continued to make agitated vocalizations throughout exposure events (Steidl and Anthony 2000). In another study, flushing distance increased as disturbance increased, suggesting habituation to either new or old stimuli is unlikely (Fraser et al. 1985).

KEY POINTS

- Eagles are especially sensitive to disturbance during **nesting season**
- **Visual screening (**vegetation, topography, man-made structures) are important factors in limiting the impacts of disturbance to eagles
- Spatial buffers of **500 m or more** should be established between eagle nest sites and recreation activities, and **75 m or more** for eagles outside of the nesting season

IMPLICATIONS FOR BALD EAGLES WASHINGTON



Current bald eagle range

Source: BirdWeb accessed 2/15/2022

Recreation should be managed to maintain healthy bald eagle populations throughout the state and is especially important during breeding and nesting periods. For locations without natural vegetative or topographic visual screening, a buffer of at least 500 m between known nesting sites and areas of popular recreation activities should be established where possible. Larger, secondary buffers of 1,200 m could reduce impacts of more disturbing activities on nesting eagles (Fraser et al. 1985, Grubb and King 1991, Steidl and Anthony 2000). Similarly, high-quality feeding and overwintering habitat may be protected outside of the nesting season by instating spatial buffers of 75 m-250 m from recreation activities (Stalmaster and Newman 1978). Maintaining trees above 40 m in height and preserving other types of vegetative cover along existing recreation corridors may serve as screening in the absence of a spatial buffer (Watson 2004). Furthermore, limiting recreational opportunities in high-quality nesting, feeding, and overwintering habitat may serve to protect the majority of eagles in a given population (Stalmaster and Newman 1978). Additional research is needed to understand how behavioral changes, especially during reproductive periods, affect bald eagles at the population level.

GOLDEN EAGLE

(*AQUILA CHRYSAETOS*)

Golden eagle (*Aquila chrysaetos*) populations in Washington exist primarily in the eastern part of the state, with preferred habitat along the east slope of the Cascade Mountains and the Blue Mountains, as well as a small breeding population on the San Juan Islands. Nesting in monogamous pairs, eagles select rocky cliffs and ledges, mature trees, and occasionally anthropogenic structures as nest sites, which they use repeatedly from year to year. Golden eagles primarily hunt small mammals in shrub-steppe, grassland, and open areas of human disturbance (e.g., clear-cuts) and are therefore dependent on availability of this habitat and an abundance of prey species.

LITERATURE FINDINGS

Literature on the impacts of recreation on golden eagles predominantly focuses on behavioral responses of nesting eagles to summer motorized recreation (ORVs, highway vehicles, and helicopters), with some examination of nest success and population change. All relevant studies took place in the western US, largely in the shrub-steppe habitat of Idaho and Utah.

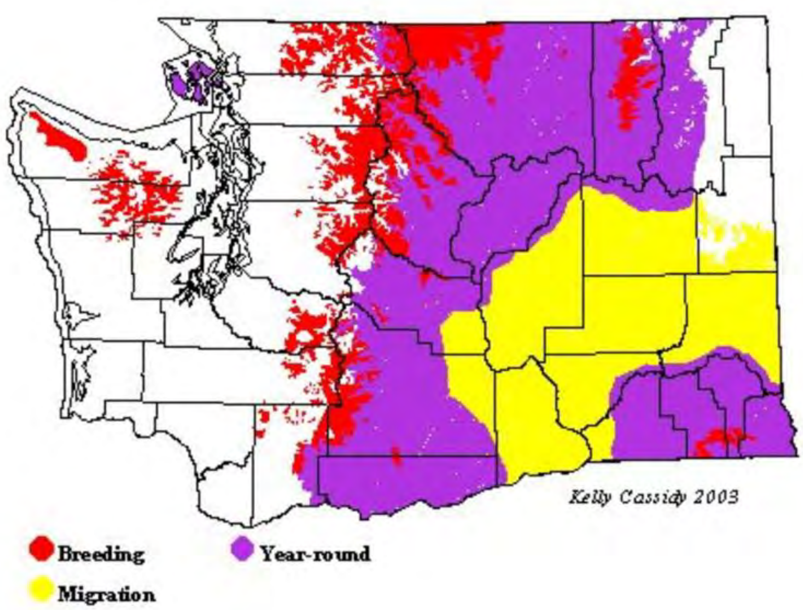
Spaul and Heath (2017) investigated the flushing response of golden eagles to motorized and non-motorized recreation within 1,200 m of an eagle nest. The majority of nesting eagles did not flush in response to recreationists but, interestingly, eagles were 60 times more likely to flush when an ORV or car stopped and recreationists began to walk. Eagles were more likely to flush in response to ORVs than to cars, and all recreation types elicited flushing sometimes except biking and horseback riding (Spaul and Heath 2017). Similarly, nesting territories were less likely to be occupied in response to higher ORV use in an area. Probability of egg laying was reduced in areas with higher amounts of hikers and other non-motorized recreation, and adult nest attendance was lower at peak times of ORV use (Spaul and Heath 2016). Further, the early portion of the breeding season is a particularly sensitive time for golden eagle activities, and recreation during this time has repeatedly been shown to decrease nest success (Spaul and Heath 2016, 2017). Analogous results by Steenhof et al. (2014) found that high ORV use caused a significant decline in territory occupancy and also decreased nest success. Additionally, nest success declined in territories closest to recreation infrastructure (e.g., trailheads, parking lots, camping sites, building facilities; Steenhof et al. 2014). The negative effects of different recreation types across golden eagle breeding and nesting season could have population level consequences by reducing breeding success (Spaul and Heath 2016). Also noteworthy, adult eagles tending chicks in Utah displayed flushing and flattening behaviors in response to helicopter flights and although no nest failure occurred, this study again reinforces the importance of disturbance mitigation during nesting (Grubb et al. 2010).

Pauli et al. (2017) used simulated golden eagle populations to project future impacts of recreational disturbances at the community level and found that although some habituation of eagles to disturbance is possible, even protective measures like spatial buffers may not be enough to thwart population decline. In 32.4% of simulations where recreation was present and increasing by as little as 1-2% annually, eagle populations declined significantly; simulations with no recreation always yielded population growth. Similarly, simulated populations protected from recreation persisted for 100 years, where those exposed to recreation went extinct within 100 years. The authors suggest that even if tolerance to disturbance occurs in a golden eagle population, it may do so at a rate that does not countervail the growth in recreational disturbance (Pauli et al. 2017).

KEY POINTS

- Eagles are especially vulnerable to disturbance during **early nesting season**
- **Transitional recreation types** are more disturbing to nesting eagles than one type of recreation alone, with ORV’s being more tolerable to eagles
- Known nesting sites and habitat should be protected from recreational activity and infrastructure by the establishment of **visual and spatial buffers**

IMPLICATIONS FOR GOLDEN EAGLES IN WASHINGTON



Current golden eagle range

Source: BirdWeb accessed 2/23/2022

On the eastern slope of the Cascade Range, substantial recreation occurs both in the subalpine and shrub-steppe regions with hiking, mountain biking, rock climbing, alpine skiing and nordic skiing directly overlapping with golden eagle nesting habitat. Summer motorized recreation (e.g., dirtbikes, ORVs) is restricted in the northern reach of this area (Okanogan-Wenatchee National Forest), but opportunities for these activities increase toward the southern end of the Cascade crest (Wenatchee National Forest, Snoqualmie National Forest). However, winter provides more possibilities for motorized recreation (e.g., snowmobiling) in all areas of this region. The easternmost range of golden eagle distribution in Washington is host to similar recreational activities but with a far lighter concentration of use.

The literature suggests seasonal closures of recreational areas near known golden eagle nest sites (Steenhof et al. 2014, Spaul and Heath 2016); thus, an inventory of Washington's nest sites is an important first step for identifying areas of concern. Developing spatial buffers between recreational travel routes, infrastructure, and nest sites (Steenhof et al. 2014), and implementing zones where motorized and fast-moving non-motorized recreationists are not permitted to stop ("no-stopping zones"; Spaul and Heath 2016) would also reduce disturbance to nesting eagles. These recommendations for protecting golden eagles are especially important in the early nesting season and should be prioritized in areas with abundant recreational access points, such as the central and southern east slope of the Cascades.

MARBLED MURRELET
(*BRACHYRAMPHUS MARMORATUS*)

Unlike other seabird species, marbled murrelets (*Brachyramphus marmoratus)* do not nest in colonies along coast lines but instead nest individually in old-growth trees of coastal forests, traveling 4 to 75 miles between marine feeding and nesting sites. Marbled murrelets have a naturally low reproductive rate because females typically obtain breeding condition only in alternate years and lay just one egg per season (April-mid September; Desimone 2016). In addition, low rates of nest initiation, high egg abandonment and nestling starvation, low prey abundance, and continued loss of old-growth forest nesting habitat all pose major threats to marbled murrelet populations (Bloxton and Raphael 2009).

LITERATURE FINDINGS

Studies of recreation impacts to murrelets are limited, with no formal studies that directly measure murrelet responses. Anecdotal observations detailed in a 2021 Oregon Department of Fish and Wildlife (ODFW) report suggest human disturbances have minimal impacts on murrelets; however, they advise not to dismiss minimal disturbances since murrelets are endangered. Marbled murrelets occur locally in small enough numbers to make even small-scale disturbances potentially impactful to their population viability. They further note that in northern California, nesting marbled murrelets experimentally exposed to the sound of chainsaws rested less during the experiment, indicating some level of disturbance to anthropogenic noise. Another study found that murrelets were less likely to nest near paved roads, perhaps avoiding increased human or predator activity along roads (ODFW 2021).

The primary concern recreation poses for murrelets centers on the elevated corvid numbers campgrounds can create. Nest predation can further decrease already low murrelet reproductive rates, and in Washington, nest predation is mostly inflicted by corvids and by Steller's jays in particular. Campgrounds, with their anthropogenic food subsidies, offer corvids important resources and can provide them access into remote forests and create areas of inflated corvid density. For murrelets, higher corvid numbers in their forested nesting habitat could mean higher nest predation of eggs and nestlings.

Two studies have examined the relationship between anthropogenic food sources at campgrounds and corvid abundance on the Olympic Peninsula, WA (Neatherlin and Marzluff 2004, Marzluff and Neatherlin 2006). Marzluff and Neatherlin (2006) found that crows, ravens, and Steller's jays displayed differing relationships to human settlements and campgrounds (campgrounds included in the study had medium to high activity with >500 campers per month, May–September). Crows were the least abundant corvid at distances >5 km from a settlement or campground, but sharply increased their abundance within 1 km of a campground. The strong relationship between crow abundance and human food sources corroborates similar findings on the Olympic Peninsula by Neatherlin and Marzluff (2004), which found that crows were more likely to occur at campgrounds and that they concentrated their use in larger campgrounds since these areas had higher human use and therefore more subsidized food sources. Ravens were moderately abundant with only slightly greater abundance near campgrounds. Conversely, Steller's jays were the most abundant corvid on the peninsula regardless of their proximity to campgrounds.

While the relationship between campgrounds, elevated corvid numbers, and increased nest predation is intuitive, it may not necessarily always be the case (Marzluff and Neatherlin 2006). In an effort to discover whether there existed a link between corvid abundance and nest predation on the Olympic Peninsula, Marzluff and Neatherlin (2006) used artificial eggs and marbled murrelet nests to test predation rates. They found that corvids predated 32.5% of artificial murrelet nests. Crows and ravens were rare nest predators, accounting for 17.6% of corvid nest predation, although their importance to predation rates increased within 1 km of settlements and campgrounds (8.2% of all predation occurred <1 km of settlements and campgrounds whereas 3.6% occurred >5 km from settlements and campgrounds). Conversely, small corvids (Steller's and gray jays) were common murrelet nest predators and were responsible for 82.4% of corvid predation. Jay's importance to nest predation did not vary by proximity to campgrounds or settlements.

Although campgrounds on the Olympic Peninsula do not appear to increase jay abundance, crow abundance was correlated with human food sources at campgrounds and settlements, which likely act as "stepping stones" for crows to exploit more remote forested areas where murrelets nest. To a lesser, but similar effect, raven abundance was somewhat correlated to campgrounds and settlements. While crows and ravens were rare marbled murrelet nest predators, their importance as predators increased in proximity to campgrounds and settlements. Thus, jay abundance may set the baseline predation rate for murrelet nests, but the variation in predation rates may be affected by campgrounds. Indeed, variation in crow abundance near settlements and campgrounds explained 50% of the variation in nest predation rates (Neatherlin and Marzluff 2004, Marzluff and Neatherlin 2006). According to these findings, campgrounds on the Olympic Peninsula *do* appear to affect corvid predation rates on marbled murrelet nests.

While campgrounds on the Olympic Peninsula did not impact Steller's jay abundance or nest predation rates, the authors mention the following noteworthy anecdotal account:

"In 1996, when flooding washed out the access road to one of the most popular visitor sites in Olympic National Park (Hoh Rainforest), visitors (and therefore food) were not allowed in the area during the breeding season. American crow and Steller's jay detections each declined by 44.6%. Raven detections remained unchanged. The probability of nest predation on simulated murrelet nests dropped from 95% (n = 22 nests in 1995, 1997–1999) to 50% (n = 6 nests in 1996)." (Marzluff and Neatherlin 2006, p. 312)

This anecdotal account indicates that in some situations on the Olympic Peninsula, Steller's jay abundance and nest predation rates *are* affected by anthropogenic food sources such as campgrounds. Indeed, two studies in California marbled murrelet range found evidence supporting a link between campgrounds and Steller's jay abundance.

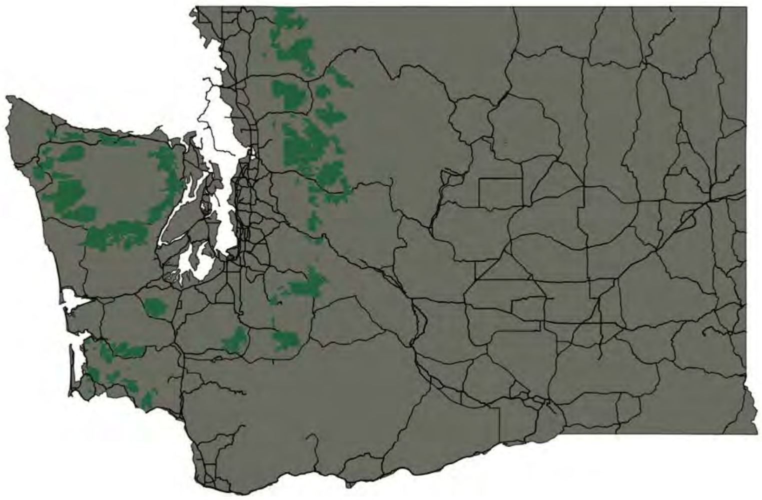
Goldenberg et al. (2016) found that while Steller's jay's home range size did not differ between campground jays and non-campground jays, the large amounts of overlap among campground-jay home ranges likely contributed to high jay abundance in campgrounds. In addition, 50% of home range use by campground jays lay outside of campgrounds; so that not only were marbled murrelets nesting within campgrounds exposed to more jays, murrelets nesting within 1 km of a campground were as well. West and Peery (2017) reported that the negative effect of campground Steller's jays may extend as far as 2 km beyond campground boundaries and that Steller's jay density, body condition, reproductive rate, and home range overlap was greater for those living in campgrounds compared to non-campground areas.

We caution that elevated Steller's jays in and near campgrounds do not necessarily mean higher predation rates on marbled murrelet nests. Goldenberg et al. (2016) also found that while campground Steller's jays did not alter their food searching behavior and maintained typical foraging activities in the forest canopy (where they may come upon a murrelet nest), they did spend less time foraging, and concentrated foraging on anthropogenic food which could reduce predation risk of murrelet nests.

KEY POINTS

- **Nest predation** by corvids, especially Steller's Jays, is a significant threat to murrelets
- Corvid abundance, and perhaps **predation of murrelet nests, can be elevated in and around campgrounds** since these sites provide anthropogenic food subsidies for corvids
- In the case of crows, **campgrounds may be the only means by which they can occupy otherwise undeveloped forests**

IMPLICATIONS FOR MARBLED MURRELETS IN WASHINGTON



Marbled murrelet critical habitat areas

Source: USFWS Federal Register 81 FR 51348

Campgrounds are especially concentrated in the murrelet nesting habitat surrounding and within the Olympic National Park. Some campgrounds exist in the Capital State Forest murrelet habitat, and there is little camping in murrelet habitat in the southwest corner of the state. South of La Grande in murrelet habitat, there is no reported formal camping, but around Mount Rainier National Park, a significant number of camping areas exist. In murrelet habitat north of Mount Rainier National Park, only few scattered campgrounds exist between Highway 410 and Highway 2. East of Granite Falls, especially along the Mountain Loop Highway, many campgrounds fall in or near murrelet habitat. A significant number of campgrounds occur in habitat north of Rockport around Baker Lake and some campgrounds are found in nesting habitat along Highway 542.

In Washington, many campgrounds already exist near and within marbled murrelet nesting habitat. At these sites, camper education on the importance of securing food and food scraps, together with animal-proof garbage cans, could lower the value of campgrounds to corvids and reduce their local abundance. Because many other anthropogenic sites such as garbage dumps, farmland, and settlements contribute enormously to elevated corvid populations, cleaning up campgrounds alone will not reduce the broader corvid population (Neatherlin and Marzluff 2004). New campground development should be limited and concentrated near existing anthropogenic food sources to contain the spread of corvid “hot spots” into other, relatively pristine forests important to nesting marbled murrelets (West and Peery 2017). In addition, because recreation infrastructure such as roads, trails, and campgrounds increase forest edges, habitat preferred by Steller's jays and other corvids, new construction of infrastructure should be limited in important nesting areas. Finally, to limit the potential impact of human disturbance to nesting murrelets, managers could consider restricting recreation activities during the breeding season in important nesting habitat. Such restrictions may be especially important for motorized recreation if limiting auditory disturbance during breeding is the desired management outcome.

SAGE-GROUSE

(*CENTROCERCUS UROPHASIANUS*)

Washington's sage-grouse (*Centrocercus urophasianus*) population is limited to two areas: the Douglas County area centered around the Moses Coulee and Mansfield Sage-grouse Management Units (SMU), and the Yakima Training Center (YTC) SMU. In the spring of 2020, 697 grouse using 17 leks remained in Douglas County, 68 grouse with 3 leks remained on the YTC, and only 10 grouse using 1 lek remained in a third small population located on the Crab Creek SMU. Late in the summer of 2020, the Pearl Hill Fire burned a large area of the Douglas County habitat, the Whitney Fire burned nearly all of the Crab Creek SMU, and the Taylor Pond Fire burned on the YTC. This loss of sage-grouse habitat is very likely to have caused considerable population declines. 2021 population estimates have not yet been published but WDFW biologists estimate 50% of the Douglas County and all of the Crab Creek populations were eliminated (Stinson 2021).

Habitat loss due to wildfires coupled with human development and habitat conversion to cropland are the biggest threats to Washington sage-grouse. Indeed, most of the literature for sage-grouse throughout the west focuses on development and habitat loss with no literature found on the effects of recreation to sage-grouse, indicating that it is not considered their most immediate threat. However, with critically low Washington sage-grouse numbers, any possible threats to sage-grouse should be identified and mitigated. Sage-grouse are reliant on mature sage brush and forbes for food and cover, thus any activities that reduce sage brush and herbaceous plant cover whether via road and trail construction, crushing of plants, or the spread of invasive weeds (which both reduce food resources and increase fire risk and spread) impact sage-grouse (Switalski 2018, D. Stinson, WDFW, personal communication). Additionally, the breeding and nesting season is a particularly sensitive time for sage-grouse populations since breeding and summer activities center around specific lek sites; human disturbance can cause lek site abandonment and lower fecundity (Lyon and Anderson 2003). In Douglas County, lek activity begins in late February with birds remaining on their summer home ranges through late summer (Stinson 2021).

LITERATURE FINDINGS

Although no studies specifically examine the effect of recreation on sage-grouse, a review by Miller et al. (2020) reports that grouse (i.e., members of the tribe Tetraonini) flush in response to recreation and avoid areas of high recreation activity. Furthermore, many studies of energy development, road impacts, and anthropogenic noise show that sage-grouse are sensitive to human disturbance and indicate ways in which recreation could impact sage-grouse. As such, the following is a discussion of sage-grouse disturbance studies that we believe lend insight on the potential of recreation to disturb sage-grouse.

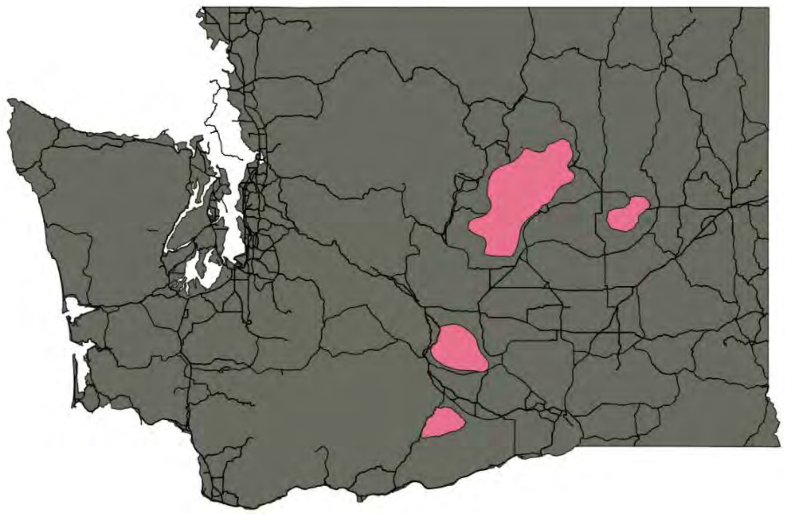
In a meta-analysis of grouse species, a majority of which (41%) were sage-grouse studies, Hovick et al. (2014) found that road presence displaced grouse and that this effect was greatest on lek sites as opposed to winter habitat or nesting and brooding habitat. Specific to sage-grouse, Lyon and Anderson (2003) monitored three lek sites along oil-development haul roads and three undisturbed leks and found that the nest-initiation rates for female grouse on disturbed and undisturbed leks were 65% and 89%, respectively. While these nest-initiation numbers were not statistically different and nest success did not differ between disturbed and undisturbed sites, the authors believed that the lower nest initiation rate for female grouse at disturbed leks was biologically significant and could lower overall productivity. In addition, they hypothesized that because habitat factors did not appear to influence nest-initiation rates, the lower nest-initiation rate for road leks was directly caused by traffic disturbance, despite low traffic rates of only 1-12 vehicles per day. Female sage-grouse at leks near roads also moved twice as far from leks to nest than those at undisturbed leks.

Lekking sage-grouse are apparently sensitive to road traffic in part due to noise. Blickley et al. (2012) experimentally treated lek sites with noise recordings of either the continuous sound of gas drilling or the intermittent sound of road traffic. They found that male attendance was 73% lower at leks treated with road noise compared to untreated leks and 29% lower at leks treated with drilling-noise compared to untreated leks. The study found little support that noise decreased female lek attendance, but there was some signature of a negative effect. Throughout the three-year study, lek attendance remained similarly lower at noise-treated sites than at untreated sites indicating no cumulative effect of noise disturbance, but also that sage-grouse did not habituate to noise. Instead, decreased lek attendance occurred in the first year, remained steadily low, and in the year following noise treatment cessation, grouse showed only a small reduction in attendance, suggesting a substantial rebound in male lek attendance. Taken together, the results of Blickley et al. (2012) suggest that anthropogenic noise, especially that of intermittent road traffic, causes male, and perhaps female, sage-grouse to avoid leks, threatening population viability of this species.

KEY POINTS

- **Breeding and nesting season is a particularly sensitive time**; lek sites are easily disturbed
- Intermittent noise and even infrequent disturbance can cause sage-grouse to **abandon leks and lead to lower nest-initiation rates**
- **Motorized recreation can indirectly impact sage-grouse** where they increase invasive plant species and fire risk

IMPLICATIONS FOR SAGE-GROUSE IN WASHINGTON



Sage-grouse habitat concentration areas

Source: WWHCWG 2010

ORV use is allowed on DNR and BLM lands during the summer, and a potential expansion of off-road ORV use on BLM land could set back important sage-grouse recovery areas (D. Stinson, WDFW, personal communication). The Moses Coulee Preserve does not allow motorized recreation. Stinson also expressed concerns for sage-grouse disturbance on WDFW lands when and where horseback riding, wilderness navigation courses, trail runs, and dog trials overlap with breeding and nesting season (D. Stinson, WDFW, personal communication).

It is unknown whether snowmobile activity overlaps with Washington sage-grouse habitat. Because most Douglas County sage-grouse populations are on private land, it is possible that snowmobile activity on these lands disturb grouse, although Stinson suspects that disturbance is limited (D. Stinson, WDFW, personal communication). There are no designated groomed routes in the Douglas County SMUs but in general, snowmobile use is allowed both on and off trail on DNR land, with the only significant parcel open to snowmobiles located along State Route 174, west of Grand Coulee. No public lands appear to have designated ski or snowshoeing areas, though all public land in Washington sage-grouse range is open to non-motorized recreation.

The YTC is open to public, non-motorized recreation when not in conflict with military training. The YTC enacts sage-grouse protection measures during the breeding season from February 1st–15th of June, closing areas designated as Sage-grouse Protection Areas. However, not all suitable and/or occupied sage-grouse habitat on the YTC is designated as Sage-grouse Protection Area. As a result, there is potential for recreation to overlap with grouse on unprotected areas year-round and on protected areas outside of the breeding season closure (C. G. Leingang, personal communication).

Further spatial analysis and interviews with local land managers are needed to identify specific locations where recreation and sage-grouse overlap beyond the general areas identified here. Public lands comprise a small portion of Washington sage-grouse habitat, but because sage-grouse numbers are extremely low and because their habitat is greatly restricted and continues to decline, preserving the integrity of small areas is important for preventing additional population decline. Where areas of overlap between recreation and sage-grouse habitat are discovered, off-road motorized recreation should be restricted to protect sage plants, prevent the spread of invasive weeds, and reduce the risk of fire ignitions. In addition, protecting breeding sage-grouse from the visual and auditory disturbance of motorized recreation is important to their breeding success. Recreation should be restricted near breeding habitat and especially near leks to avoid disturbing breeding activities. While non-motorized recreation may be quieter, hikers, bikers, wildlife viewers, and photographers also directly disturb lekking activities and should be similarly restricted around leks during the breeding season.

IMPLICATIONS

Many of the broad scale wildlife-recreation trends identified by Larsen et al. (2016, 2019) and Miller et al. (2020) were reflected in this report: the effects of recreation on wildlife are mostly negative; animals tended to have stronger responses to less predictable forms of recreation; reproductive status was important for individuals encountering recreation; seasonal responses differed between summer and winter; and habitat generalists were typically less vulnerable than habitat specialists. In addition, many of the wildlife species in this report followed patterns commonly documented in the wildlife-recreation literature: they temporally adjusted activity to avoid recreation; were increasingly impacted by higher intensities of recreation; and were most affected by non-motorized recreation (but note a key caveat that the geographic footprint of motorized recreation is generally far larger than that of non-motorized recreation). Indeed, all of the species in this report have the potential to be negatively impacted by recreation in Washington given the right circumstances. These circumstances include a) where recreation overlaps with species ranges, especially in critical habitats and at vulnerable times of the day, year, or life history periods, b) when the intensity and frequency of recreation within the overlap area is high enough to elicit a negative population-level effect, and c) when the footprint of overlap is so extensive that animals do not have high-quality refugia habitat to escape to. In such areas where the above circumstances occur, site-specific management actions should be enacted to mitigate the effects of recreation.

Identifying recreation-wildlife overlap in Washington

A clear first step to identifying potential areas of conflict between recreation and wildlife in Washington requires mapping recreation areas and overlaying this data with either current or historic range maps for species of concern. This is a fundamental objective to better understand wildlife-recreation dynamics and is invaluable for identifying priority areas to address overlap. Mapping is especially important in areas where recreation overlaps with critical habitats or may inordinately impact a given species during vulnerable times in its life history. However, at present we are unaware of a centralized database that could be used for this purpose; maps of all motorized and non-motorized trails, locations of off-trail activities such as backcountry skiing, snowmobiling, or rock climbing, and unauthorized user-built trails are critical for understanding recreation's footprint in Washington.

Geographic Information System (GIS) data that map trails and motorized roads are available through the various public land agencies and could provide a valuable starting point for mapping recreation in Washington; however, this data may be incomplete or outdated. An effort to obtain data on active roads, trails, and other dispersed recreation areas is needed to comprehensively depict the extent of wildlife-recreation overlap. In addition to GIS mapping, communicating with local land managers and documenting locally important areas of wildlife-recreation overlap may help to elucidate priority areas that are not represented by mapping data.

Measuring recreation frequencies and intensities

Wildlife managers need to collect local data that quantifies recreation intensity and frequency in Washington. This data, when coupled with information about the threshold at which recreation negatively impacts a species of concern, is critical for identifying problematic areas of overlap. For example, lynx in Colorado were shown to coexist with low to moderate levels of winter recreation; however, developed ski areas with high levels of recreation were not used by lynx, suggesting an upper limit to the level of recreation lynx tolerated (Olsen et al. 2018). Similarly, wolverines, especially females, avoided areas with off-road motorized winter recreation at increasing intensities (Heinemeyer et al. 2019). Whether lynx or wolverines in Washington experience recreation at an intensity level high enough to elicit a negative response is unknown, leaving uncertainty as to whether recreation currently poses a risk to these populations. Additionally, short-term effects of recreation on wildlife may not always amount to distribution or population-level effects. Thus, research that bridges the gap between short- and long-term effects in relation to recreation intensity should be prioritized where possible. Quantifying recreation intensity levels is critical for inferring whether the negative impacts of recreation identified in the literature may be occurring in Washington. When paired with the aforementioned mapping efforts, this data would help to both prioritize and most effectively manage recreation impacts on wildlife.

Protecting spatial and temporal refugia

Many wildlife species will adjust their activity patterns or space use to avoid intense places and periods of recreation, where this ability to alter their behavior is the primary reason they are able to coexist with recreation. As a result, protecting both spatial and temporal refugia into which wildlife can shift their activity is a crucial conservation concern (Lewis et al. 2021) and can be identified for Washington species by conducting the aforementioned mapping analysis. Access to high-quality refugia habitat is important for most species exposed to recreation, especially for vulnerable species that are particularly sensitive to disturbance. For example, caribou avoid entire areas of otherwise high-quality habitat when used by snowmobiles (Seip et al. 2007) and thus require adjacent, undisturbed, high-quality habitat into which they can escape. Further, protecting critical habitats for over-wintering and reproducing animals, including breeding, birthing, nesting, and denning habitats is required to support healthy wildlife populations. This is particularly important for vulnerable species that require specific and limited habitats for reproduction and over-wintering, such as sage-grouse, wolverine, and mule deer (Lyon and Anderson 2003, Heinemeyer et al. 2019, Stinson 2021). In addition, where recreation already exists, seasonal closures and/or restricting off-road and off-trail use can protect important habitat during vulnerable seasons and life history phases.

One of the most important actions to ensure wildlife-recreation coexistence is to protect refugia by limiting the spatial footprint of recreation. Recreationists are often encouraged to improve their experience in the outdoors by dispersing from crowded areas to seek lesser-used areas. We instead urge land managers, policy makers, and the tourism and recreation industry to educate recreationists about the importance of reducing their recreation footprint, to consolidate recreation into areas with lower value to wildlife, and to build more compact trail networks to limit habitat fragmentation and the spatial footprint of recreation. Furthermore, reducing road densities through wildland areas by decommissioning select unmaintained roads and limiting the construction of new roads would also limit the spatial footprint of recreation.

Similarly, temporal refugia are critical for wildlife species that behaviorally adapt to recreation by changing activity or space use patterns during day-time hours when recreationists are most active (Lewis et al. 2021). For example, bighorn sheep will spend time farther from trails during the day and especially on weekends, but move closer to trails at night (Longshore et al. 2013, Marchand et al. 2014). Many ungulate species display this type of behavioral shift, and it also occurs in carnivore species such as black bears and grizzly bears (Lewis et al. 2021, Naidoo and Burton 2020, Fortin et al. 2016). As a result, limiting recreational activities during nighttime hours can allow animals with behavioral plasticity to persist in areas with recreation and help to promote wildlife-recreation coexistence. However, managers should carefully consider the normal behavior of local species, as even wildlife that are willing to shift diel activity temporally may experience negative effects such as increased exposure to predation or a decrease in hunting opportunities.

Implementing management actions

Identifying recreation and wildlife overlap, quantifying recreation intensity and frequencies, and protecting spatial and temporal refugia across the state of Washington will highlight potential areas of conflict. Once these areas are identified, mitigation strategies informed by the best available science for a given species can be implemented. The species accounts in this report provide management implications recommended by the literature and highlight known sensitivities of wildlife species in Washington. These recommendations provide a starting point and can be iterated upon to develop additional management actions and policies.

Few Washington-based recreation and wildlife studies exist and as a result, conservationists, managers, and policy makers must make inferences as to whether studies conducted under different circumstances apply to Washington wildlife populations. To ensure that conclusions and management recommendations from the existing literature apply similarly to wildlife living in the context of Washington landscapes and recreation effects, local research is needed. For example, studies of lynx in Montana concluded that snowmobile trails did not facilitate coyote movement into lynx habitat (Kolbe et al. 2007) while a study in Wyoming found that snowmobiles did (Dowd et al. 2014). These contrasting results are likely due to differences in snowpack between the two areas and exemplify the importance of local research.

Despite the lack of local research in Washington, the incomplete picture of recreation impacts to wildlife should not act as a paralytic to action. When local studies are not feasible or would delay action in urgent situations, we suggest adaptive management as the most effective and impactful way for conservation practitioners to actively mitigate recreation impacts. In the adaptive management framework, practices developed using the best available science can be implemented quickly and adjusted in response to ongoing monitoring efforts that measure wildlife response with respect to the implemented action (Bateman and Flemming 2017). Furthermore, these adaptive management practices resemble traditional ecological knowledge systems that emphasize feedback learning and account for the inherent uncertainty in ecological understanding (Berkes et al. 2000).

CONCLUSION

There is still much to learn about wildlife-recreation dynamics. Focus on the key areas discussed above will help to elucidate the extent of the recreation footprint in Washington and highlight places and times when recreation may threaten particular wildlife species. Many of the species discussed in this report are imperiled in Washington State including Canada lynx, grizzly bear, sage-grouse, marbled murrelet, wolverine, bighorn sheep, and mountain caribou. While recreation is not the primary reason behind these species' declines, even a small amount of range overlap with recreation in important habitats and during sensitive periods could prove detrimental for animals especially sensitive to human disturbance. Small populations spiraling towards extinction become increasingly vulnerable so that even slight disturbances from recreation could significantly reduce population viability. Additionally, species of least concern that exhibit sensitivities to recreation warrant careful attention since increasing recreation could result in range reductions or decreased population viability. As such, we encourage conservation practitioners to carefully consider potential recreation impacts on threatened and endangered species, while also closely monitoring and protecting all sensitive species from increasing recreation.

As human populations continue to grow, wildlife increasingly face myriad human-induced challenges that impact biodiversity and have triggered the planet's sixth mass extinction (Ceballos et al. 2015). Outdoor recreation impacts are a piece of this larger puzzle, and the recent increases in outdoor recreation participation highlight an urgent and immediate need to both better understand and mitigate recreational impacts on wildlife. The information within this report provides a starting point for conservation practitioners seeking to limit biodiversity loss and encourage wildlife-recreation coexistence in Washington into the future.

LITERATURE CITED

Aastrup, P. (2000). Responses of West Greenland caribou to the approach of humans on foot. *Polar Research, 19*(1), 83-90.

Anthony, R. G., R. J. Steidl, and McGarigal, K. (1995). Recreation and bald eagles in the Pacific Northwest. pp. 223-241, *in R. L. Knight and K.J.Gutzwiller. Wildlife and Recreationists: coexistence through management and research.* Island Press, Washington, D.C.

Bateman, P. W., and Fleming, P. A. (2017). Are negative effects of tourist activities on wildlife over-reported? A review of assessment methods and empirical results. *Biological Conservation*, *211*, 10-19.

Belotti, E., Heurich, M., Kreisinger, J., Šustr, P., and Bufka, L. (2012). Influence of tourism and traffic on the Eurasian lynx hunting activity and daily movements. *Animal Biodiversity and Conservation*, *35*(2), 235-246.

Berkes, F., Colding, J., and Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological applications*, *10*(5), 1251-1262.

BirdWeb - Bald Eagles. (n.d.). Accessed February 23, 2022, from http://www.birdweb.org/birdweb/bird/bald_eagle

BirdWeb - Golden Eagles. (n.d.). Accessed February 23, 2022, from http://www.birdweb.org/birdweb/bird/golden_eagle

Blickley, J. L., Blackwood, D., and Patricelli, G. L. (2012). Experimental evidence for the effects of chronic anthropogenic noise on abundance of greater sage-grouse at leks. *Conservation Biology*, *26*(3), 461-471.

Bloxton, T.D., and M.G. Raphael. (2009). Breeding ecology of the marbled murrelet in Washington State: five year project summary (2004-2008). USDA Forest Service, Pacific Northwest Research Station, Olympia, Washington.

Borkowski, J.J., White, P. J., Garrott, R. A., Davis, T., Hardy, A. R., and Reinhart, D. J. (2006). Behavioral responses of bison and elk in Yellowstone to snowmobiles and snow coaches. *Ecological Applications*, *16*(5), 1911– 1925.

Bunnell, K. D., Flinders, J. T., and Wolfe, M. L. (2006). Potential impacts of coyotes and snowmobiles on lynx conservation in the intermountain west. *Wildlife Society Bulletin*, *34*(3), 828-838.

Buskirk, S. W. (2000). Habitat fragmentation and interspecific competition: Implications for lynx conservation [Chapter 4]. *In: Ruggiero, Leonard F.; Aubry, Keith B.; Buskirk, Steven W.; Koehler, Gary M.; Krebs, Charles J.; McKelvey, Kevin S.; Squires, John R. Ecology and conservation of lynx in the United States. Gen. Tech. Rep. RMRS-GTR-30WWW.*

Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 83-100., *30*, 83-100.

Cadsand, B. A. (2012). *Responses of mountain goats to heliskiing activity: movements and resource selection* (Doctoral dissertation, University of Northern British Columbia).

Cassirer, E., Freddy, D., and Ables, E. (1992). Elk responses to disturbance by cross-country skiers in Yellowstone National Park. *Wildlife Society Bulletin, 20*(4), 375-381.

Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M., and Palmer, T. M. (2015). Accelerated modern human–induced species losses: Entering the sixth mass extinction. *Science advances*, *1*(5), e1400253.

Ciuti, S Northrup, J. M., Muhly, T. B., Simi, S., Musiani, M., Pitt, J. A., and Boyce, M. S. (2012). Effects of humans on behaviour of wildlife exceed those of natural predators in a landscape of fear. *PloS One*, *7*(11), e50611–e50611.

Colman, J., Jacobsen, B., and Reimers, E. (2001). Summer response distances of Svalbard reindeer (*Rangifer tarandus platyrhynchus*) to provocation by humans on foot. *Wildlife Biology, 7*(4), 275-283.

Coppes, J., Burghardt, F., Hagen, R., Suchant, R., and Braunisch, V. (2017). Human recreation affects spatio-temporal habitat use patterns in red deer (*Cervus elaphus*). *PloS One, 12*(5), E0175134.

Costello, C. M., Cain, S. I., Nielson, R. M., Servheen, C., and Schwartz, C. C. (2013). Response of American black bears to the non-motorized expansion of a road corridor in Grand Teton National Park. *Ursus*, *24*(1), 54–69. https://doi.org/10.2192/URSUS-D-11-00027.1

Côté, S. D. (1996). Mountain goat response to helicopter disturbance. *Wildlife Society Bulletin,* 24(4), 681-685.

Côté, S. D., Hamel, S., St-Louis, A., and Mainguy, J. (2013). Do mountain goats habituate to helicopter disturbance? *The Journal of wildlife management*, *77*(6), 1244-1244.

Courtemanch, A. B., (2014). Seasonal habitat selection and impacts of backcountry recreation on a formerly migratory bighorn sheep population in northwest Wyoming, USA. M.S. Thesis, Department of Zoology and Physiology, May 2014.

Creel, S., Fox, J. E., Hardy, A., Sands, J., Garrott, B., and Peterson, R. O. (2002). Snowmobile activity and glucocorticoid stress responses in wolves and elk. *Conservation Biology*, *16*(3), 809–814.

Cristescu, B., Stenhouse, G. B., and Boyce, M. S. (2013). Perception of human-derived risk influences choice at top of the food chain. *PLoS One*, *8*(12), e82738.

Crupi, A. P., Gregovich, D. P., and White, K. S. (2020). Steep and deep: Terrain and climate factors explain brown bear (*Ursus arctos*) alpine den site selection to guide heli-skiing management. *PloS One*, *15*(9), e0238711.

Desimone, S. M. 2016. Periodic status review for the marbled murrelet in Washington. Washington Department of Fish and Wildlife, Olympia, Washington. 28+iii pp.

Dixon, G., Marriott, A., Stelfox, G., Dunkerley, C., and Batke, S. (2021). How do red deer react to increased visitor numbers? A case study on human-deer encounter probability and its effect on cortisol stress responses. *Nature Conservation, 43*(2), 55-78.

Dowd, J. L., Gese, E. M., and Aubry, L. M. (2014). Winter space use of coyotes in high-elevation environments: behavioral adaptations to deep-snow landscapes. *Journal of Ethology*, *32*(1), 29-41.

Duchesne, M., Côté, S., and Barrette, C. (2000). Responses of woodland caribou to winter ecotourism in the Charlevoix Biosphere Reserve, Canada. *Biological Conservation, 96*(3), 311-317.

Dunn, W. C. (1996). Evaluating bighorn habitat: a landscape approach. Technical Note 395. US Department of the Interior, Bureau of Land Management.

Duffy, R.J. (2020). Outdoor Recreation and Tourism in the United States. Environmental Issues Today: Choices and Challenges [2 volumes], p.117.

Endangered and Threatened Wildlife and Plants; Determination of Critical Habitat for the Marbled Murrelet, 81 FR 51348, (November 4, 2011).

Erb, P. L., McShea, W. J., and Guralnick, R. P. (2012). Anthropogenic influences on macro-level mammal occupancy in the Appalachian trail corridor. *PLoS ONE*, *7*(8).

Ferguson, M and Keith, L. (1981). Interactions of nordic skiers with ungulates in Elk Island National Park. 10.13140/RG.2.1.4286.3608.

Ferguson, M. A., and Keith, L. B. (1982). Influence of Nordic skiing on distribution of moose and elk in Elk Island National Park, Alberta. *Canadian field-naturalist. Ottawa ON*, *96*(1), 69-78.

Ferris, R. M. (1989). *Responses of black-tailed deer to off-highway vehicles*. San Jose State University.

Fortin, J. K., Rode, K. D., Hilderbrand, G. v, Wilder, J., Farley, S., Jorgensen, C., and Marcot, B. G. (2016). Impacts of human recreation on brown bears (*Ursus arctos*): A review and new management tool. *PloS One*, *11*(1), e0141983.

Fraser, J., Frenzel, L., and Mathisen, J. (1985). The impact of human activities on breeding bald eagles in north-central Minnesota. *The Journal of Wildlife Management, 49*(3), 585-592.

Freddy, D. J., Bronaugh, W. M., and Fowler, M. C. (1986). Responses of mule deer to disturbance by persons afoot and snowmobiles. *Wildlife Society Bulletin (1973-2006)*, *14*(1), 63-68.

Frid, A. (2003). Dall's sheep responses to overflights by helicopter and fixed-wing aircraft. *Biological Conservation 110, 387–399*.

Gaines, W. L., Singleton, P. H., and Ross, R. C. (2003). Assessing the cumulative effects of linear recreation routes on wildlife habitats on the Okanogan and Wenatchee National Forests. *Gen. Tech. Rep. PNW-GTR-586. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 79 p*, *586*.

Gaynor, K., Hojnowski, C., Carter, N., and Brashares, J. (2018). The influence of human disturbance on wildlife nocturnality. *Science (American Association for the Advancement of Science), 360*(6394), 1232-1235

Geist, V. (1971). Mountain sheep: a study in behavior and evolution. Univ. Chicago Press, Chicago. 383pp.

George, S. L., and Crooks, K. R. (2006). Recreation and large mammal activity in an urban nature reserve. *Biological Conservation*, *133*(1), 107-117.

Goldenberg, W. P., George, T. L., and Black, J. M. (2016). Steller's Jay (*Cyanocitta stelleri*) space use and behavior in campground and non-campground sites in coastal redwood forests. *The Condor: Ornithological Applications*, *118*(3), 532-541.

Goldstein, M. I., Poe, A. J., Suring, L. H., Nielson, R. M., and McDonald, T. L. (2010). Brown bear den habitat and winter recreation in South-Central Alaska. *The Journal of Wildlife Management*, *74*(1), 35–42.

Goodrich, J. M., and Berger, J. (1993). Winter recreation and hibernating black bears (*Ursus americanus*). *Biological Conservation*, *67*(2), 105–110.

Green, R. J., and Higginbottom, K. (2000). The effects of non-consumptive wildlife tourism on free-ranging wildlife: a review. *Pacific Conservation Biology*, 6(3), 183–197.

Grubb, T., and King, R. (1991). Assessing human disturbance of breeding bald eagles with classification tree models. *The Journal of Wildlife Management, 55*(3), 500-511.

Grubb, T., Delaney, D., Bowerman, W., and Wierda, M. (2010). Golden Eagle Indifference to Heli-Skiing and Military Helicopters in Northern Utah. *The Journal of Wildlife Management, 74*(6), 1275-1285.

Harris, G., Nielson, R., Rinaldi, T., and Lohuis, T. (2013). Effects of winter recreation on northern ungulates with focus on moose (*Alces alces*) and snowmobiles. *European Journal of Wildlife Research, 60*(1), 45-58.

Heinemeyer, K. J., and Squires, J. P. (2013). Wolverine-winter recreation research project: Investigating the interactions between wolverines and winter recreation 2013 Progress Report. Retrieved March 15, 2022, from www.forestcarnivores.org

Heinemeyer, K., Squires, J., Hebblewhite, M., O'Keefe, J. J., Holbrook, J. D., and Copeland, J. (2019). Wolverines in winter: indirect habitat loss and functional responses to backcountry recreation. *Ecosphere*, *10*(2), e02611.

Hennings, L. (2017). Hiking, mountain biking and equestrian use in natural areas: A recreation ecology literature review. Technical report: Oregon Metro Parks and Nature. Portland, Oregon.

Hicks, L., and Elder, J. (1979). Human disturbance of Sierra Nevada bighorn sheep. *The Journal of Wildlife Management, 43*(4), 909-915.

Hoglander, C., Dickson, B., Rosenstock, S., and Anderson, J. (2015). Landscape models of space use by desert bighorn sheep in the Sonoran Desert of southwestern Arizona. *The Journal of Wildlife Management, 79*(1), 77-91.

Holl, S. A. (1982) Evaluation of bighorn sheep habitat. Desert Bighorn Council Trans. 34:14-22.

Holzschuh. (2016). Does rock climbing threaten cliff biodiversity? - A critical review. *Biological Conservation*, *204*, 153–162.

Horejsi, B. L. (1981). Behavioral response of barren ground caribou to a moving vehicle. Arctic, 24, 180-5.

Hovick, T. J., Elmore, R. D., Dahlgren, D. K., Fuhlendorf, S. D., and Engle, D. M. (2014). Evidence of negative effects of anthropogenic structures on wildlife: a review of grouse survival and behaviour. *Journal of Applied Ecology*, *51*(6), 1680-1689.

Jayakody, S., Sibbald, A., Gordon, I., and Lambin, X. (2008). Red Deer (*Cervus elephus*) vigilance behaviour differs with habitat and type of human disturbance. *Wildlife Biology, 14*(1), 81-91.

Jensen, W. F., Fuller, T. K., and Robinson, W. L. (1986). Wolf, (*Canis lupus*), distribution on the Ontario-Michigan border near Sault Ste. Marie. *Canadian Field-Naturalist*. 100(3): 363–366.

Johnson, R. L., and Lockard, F. R. (1983). *Mountain goats and mountain sheep of Washington* (No. 18). Washington Department of Game.

Kays, R., Parsons, A. W., Baker, M. C., Kalies, E. L., Forrester, T., Costello, R., … McShea, W. J. (2017). Does hunting or hiking affect wildlife communities in protected areas? *Journal of Applied Ecology*, *54*(1), 242–252.

King, M. M., (1985). Behavioral response of desert bighorn sheep to human harassment: A comparison of disturbed and undisturbed populations. Utah State University. *Graduate Thesis*.

Kolbe, J. A., Squires, J. R., Pletscher, D. H., and Ruggiero, L. F. (2007). The effect of snowmobile trails on coyote movements within lynx home ranges. *The Journal of wildlife management*, *71*(5), 1409-1418.

Knight, R. L., and Cole, D. N. (1991). Effects of recreational activity on wildlife in wildlands. *In Transactions of the North American Wildlife and Natural Resources Conference* (USA).

Krebs, J., Lofroth, E. C., and Parfitt, I. A. N. (2007). Multiscale habitat use by wolverines in British Columbia, Canada. *The Journal of Wildlife Management*, *71*(7), 2180–2192.

Ladle, A., Avgar, T., Wheatley, M., Stenhouse, G. B., Nielsen, S. E., and Boyce, M. S. (2019). Grizzly bear response to spatio-temporal variability in human recreational activity. *Journal of Applied Ecology*, *56*(2), 375–386.

Ladle, A., Steenweg, R., Shepherd, B., and Boyce, M. S. (2018). The role of human outdoor recreation in shaping patterns of grizzly bear-black bear co-occurrence. *PLoS One*, *13*(2), e0191730.

Larson, C. L., Reed, S. E., Merenlender, A. M., and Crooks, K. R. (2016). Effects of recreation on animals revealed as widespread through a global systematic review. *PloS one*, *11*(12), e0167259.

Larson, C. L., Reed, S. E., Merenlender, A. M., and Crooks, K. R. (2019). A meta-analysis of recreation effects on vertebrate species richness and abundance. *Conservation Science and Practice*, *1*(10), e93.

Larson, C. L., Reed, S. E., and Crooks, K. R. (2020). Increased hiking and mountain biking are associated with declines in urban mammal activity. California Fish and Wildlife, 52.

Lenth, B. E., Knight, R. L., and Brennan, M. E. (2008). The effects of dogs on wildlife communities. *Natural Areas Journal*, *28*(3), 218-227.

Lesmerises, F., Johnson, C., and St-Laurent, M. (2017). Refuge or predation risk? Alternate ways to perceive hiker disturbance based on maternal state of female caribou. *Ecology and Evolution, 7*(3), 845-854.

Lewis, J. C. (2019). Periodic status review for the grizzly bear in Washington. Washington Department of Fish and Wildlife, Olympia, Washington.

Lewis, J. S., Spaulding, S., Swanson, H., Keeley, W., Gramza, A. R., VandeWoude, S., and Crooks, K. R. (2021). Human activity influences wildlife populations and activity patterns: implications for spatial and temporal refuges. *Ecosphere*, *12*(5), e03487.

Link, R., Beausoleil, R., and Spencer, R. (2007). Living with wildlife: black bears. Washington Department of Fish and Wildlife, Olympia, Washington.

Linnell, J. D., Swenson, J. E., Andersen, R., and Barnes, B. (2000). How vulnerable are denning bears to disturbance? *Wildlife Society Bulletin*, 400-413.

Loehr, J., Kovanen, M., Carey, J., Hogmander, H., Jurasz, C., Karkkainen, S., and Ylonen, H. (2005). Gender- and age-class-specific reactions to human disturbance in a sexually dimorphic ungulate. *Canadian Journal of Zoology, 83*(12), 1602-1607.

Longshore, K., Lowrey, C., and Thompson, D. (2013). Detecting short-term responses to weekend recreation activity: Desert bighorn sheep avoidance of hiking trails. *Wildlife SocietyBulletin, 37*(4), 698-706.

Lowrey, C., and Longshore, K. (2017). Tolerance to disturbance regulated by attractiveness of resources: A case study of desert bighorn sheep within the River Mountains, Nevada. *Western North American Naturalist, 77*(1), 82-98.

Lyon, A. G., and Anderson, S. H. (2003). Potential gas development impacts on sage grouse nest initiation and movement. *Wildlife society bulletin*, 486-491.

MacArthur, R., Geist, V., and Johnston, R. (1982). Cardiac and behavioral responses of mountain sheep to human disturbance. *The Journal of Wildlife Management, 46*(2), 351-358.

Mahoney, S.P. and Mawhinney, K. and McCarthy, C. and Anions, Doug and Taylor, S. (2001). Caribou reactions to provocation by snowmachines in Newfoundland. Rangifer. 21. 35. 10.7557/2.21.1.1526.

Marchand, P., Garel, M., Bourgoin, G., Dubray, D., Maillard, D., and Loison, A. (2014). Impacts of tourism and hunting on a large herbivore's spatio-temporal behavior in and around a French protected area. *Biological Conservation,* (*177*) 1-11.

Martinetto, K., and Cugnasse, J. M. (2001). Reaction distance in Mediterranean mouflon (*Ovis gmelini musimon x Ovis sp*.) in the presence of hikers with a dog on the Caroux plateau (Herault, France). *Revue d'écologie*.

Martínez-Abraín, A., Oro, D., Jiménez, J., Stewart, G., and Pullin, A. (2010). A systematic review of the effects of recreational activities on nesting birds of prey. *Basic and Applied Ecology, 11*(4), 312-319.

Marzano, M., and Dandy, N. (2012). Recreationist behaviour in forests and the disturbance of wildlife. *Biodiversity and Conservation*, *21*(11), 2967-2986.

Marzluff, J. M., and Neatherlin, E. (2006). Corvid response to human settlements and campgrounds: causes, consequences, and challenges for conservation. *Biological conservation*, *130*(2), 301-314.

McCarthy, K., and Fletcher Jr, R. (2015). Does hunting activity for game species have indirect effects on resource selection by the endangered Florida panther? *Animal Conservation, 18*(2), 138-145.

McKelvey, K. S., Copeland, J. P., Schwartz, M. K., Littell, J. S., Aubry, K. B., Squires, J. R., Mauger, G. S. (2011). Climate change predicted to shift wolverine distributions, connectivity, and dispersal corridors. *Ecological Applications*, *21*(8), 2882–2897.

Miller, A. B., King, D., Rowland, M., Chapman, J., Tomosy, M., Liang, C., and Truex, R. L. (2020). Sustaining wildlife with recreation on public lands: A synthesis of research findings, management practices, and research needs. *Gen. Tech. Rep. PNW-GTR-993. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 226 p. 993*.

Miller, S. G., Knight, R. L., and Miller, C. K. (2001). Wildlife responses to pedestrians and dogs. *Wildlife Society Bulletin*, 124-132.

Milo Burcham, W. Daniel Edge, and C. Les Marcum. (1999). Elk use of private land refuges. *Wildlife Society Bulletin*, *27*(3), 833–839.

Montgomery, R. A., Roloff, G. J., Millspaugh, J. J., and Nylen-Nemetchek, M. (2014). Living amidst a sea of agriculture: predicting the occurrence of Canada lynx within an ecological island. *Wildlife Biology*, *20*(3), 145-154.

Morrison, C., Boyce, M., Nielsen, S., and Bacon, M. (2014). Habitat selection of a re-colonized cougar population in response to seasonal fluctuations of human activity. *The Journal of Wildlife Management, 78*(8), 1394- 1403.

Mountain Goat Management Team. (2010). Management plan for the mountain goat (*Oreamnos americanus*) in British Columbia. Prepared for the B.C. Ministry of Environment, Victoria, Canada.

Musiani, M., Anwar, S. M., McDermid, G. J., Hebblewhite, M., and Marceau, D. J. (2010). How humans shape wolf behavior in Banff and Kootenay National Parks, Canada. *Ecological Modelling*, *221*(19), 2374–2387.

Naidoo, R., and Burton, A. C. (2020). Relative effects of recreational activities on a temperate terrestrial wildlife assemblage. *Conservation Science and Practice*, *2*(10), 1–10.

Naylor, L.M., Wisdom, M.J., and G. Anthony, R. (2009). Behavioral responses of North American elk to recreational activity. The Journal of Wildlife Management, 73(3), 328–338.

Neatherlin, E. A., and Marzluff, J. M. (2004). Responses of American crow populations to campgrounds in remote native forest landscapes. *The Journal of Wildlife Management*, *68*(3), 708-718.

Nelson, L.H., Bailey, D., 2021. The “Recreation Boom” on public lands in Western Washington: Impacts to Wildlife and Implications for Treaty Tribes A Summary of Current Literature.

Nickel, B., Suraci, J., Allen, M., and Wilmers, C. (2020). Human presence and human footprint have non-equivalent effects on wildlife spatiotemporal habitat use. *Biological Conservation,* (*241*), 108383.

Nix, J. H., Howell, R. G., Hall, L. K., and McMillan, B. R. (2018). The influence of periodic increases of human activity on crepuscular and nocturnal mammals: Testing the weekend effect. *Behavioural Processes*, *146*, 16-21.

Oberosler, V., Groff, C., Iemma, A., Pedrini, P., and Rovero, F. (2017). The influence of human disturbance on occupancy and activity patterns of mammals in the Italian Alps from systematic camera trapping. *Mammalian Biology*, *87*(1), 50–61.

Oberosler, V., Tenan, S., and Rovero, F. (2020). Spatial and temporal patterns of human avoidance by brown bears in a reintroduced population. *Hystrix*, *31*(2).

ODFW. 2021. Biological Assessment of the Marbled Murrelet (*Brachyramphus marmoratus*) in Oregon and evaluation of criteria to reclassify the species from threatened to endangered under the Oregon Endangered Species Act. Report prepared for the Oregon Fish and Wildlife Commission, June 2021. Oregon Department of Fish and Wildlife, Salem, Oregon.

Morhman, M. *State population steadily increases, tops 7.7 million residents in 2021*. Office of Financial Management. Retrieved March 15, 2022, from https://ofm.wa.gov/about/news/2021/06/state-population-steadily-increases-tops-77-million-residents-2021

Nature Mapping - Mountain lions (n.d.). Retrieved March 15, 2022, from http://naturemappingfoundation.org/natmap/maps/wa/#mammals

Olliff, T., Legg, K., Kaeding, B. (Eds.), 1999. Effects of winter recreation on wildlife of the Greater Yellowstone Area: a literature review and assessment. *Report to the Greater Yellowstone Coordinating Committee*. Yellowstone National Park, WY, pp.315.

Olson, L. E., Squires, J. R., Roberts, E. K., Ivan, J. S., and Hebblewhite, M. (2018). Sharing the same slope: behavioral responses of a threatened mesocarnivore to motorized and nonmotorized winter recreation. *Ecology and evolution*, *8*(16), 8555-8572.

Outdoor Industry. *2021 Outdoor Participation Trends Report* (n.d.). Retrieved March 15, 2022, from https://outdoorindustry.org/wp-content/uploads/2015/03/2021-Outdoor-Participation-Trends-Report.pdf

Papouchis, C., Singer F., and Sloan, W. (2001). Responses of desert bighorn sheep to increased human recreation. *The Journal of Wildlife Management, 65*(3), 573-582.

Pauli, B., Spaul, R., and Heath, J. (2017). Forecasting disturbance effects on wildlife: Tolerance does not mitigate effects of increased recreation on wildlands. *Animal Conservation, 20*(3), 251-260.

Phillips, G.E. and Alldredge, A. W. (2000). Reproductive success of elk following disturbance by humans during calving season. *The Journal of Wildlife Management*, *64*(2), 521–530.

Preisler, H.K., Ager, A. A., and Wisdom, M. J. (2006). Statistical methods for analysing responses of wildlife to human disturbance. The Journal of Applied Ecology, 43(1), 164–172.

Price, M. V., Strombom, E. H., and Blumstein, D. T. (2014). Human activity affects the perception of risk by mule deer. *Current Zoology*, *60*(6), 693-699.

Proposed Determination of Critical Habitat for Grizzly Bear; 41 FR 48757 48759 (November 5, 1976).

Reed, S., and Merenlender, A. (2011). Effects of management of domestic dogs and recreation on carnivores in protected areas in Northern California. *Conservation Biology,25*(3), 504-513.

Reilly, M. L., Tobler, M. W., Sonderegger, D. L., and Beier, P. (2017). Spatial and temporal response of wildlife to recreational activities in the San Francisco Bay ecoregion. *Biological Conservation*, *207*, 117-126.

Reimers, E., Eftestøl, S., and Colman, J. (2003). Behavior responses of wild reindeer to direct provocation by a snowmobile or skier. *The Journal of Wildlife Management, 67*(4), 747-754.

Reimers, E., Miller, F., Eftestøl, S., Colman, J., and Dahle, B. (2006). Flight by feral reindeer (*Rangifer tarandus tarandus*) in response to a directly approaching human on foot or on skis. *Wildlife Biology, 12*(4), 403- 413.

Reimers, E., Røed, K., Flaget, and., and Lurås, E. (2010). Habituation responses in wild reindeer exposed to recreational activities. *Rangifer, 30*(1), 45-59.

Revised Designation of Critical Habitat for the Contiguous United States Distinct Population Segment of the Canada Lynx and Revised Distinct Population Segment Boundary; Final Rule, 79 FR 54781 54846, (September 4, 2014).

Richard, J. H., and Côté, S. D. (2016). Space use analyses suggest avoidance of a ski area by mountain goats. *The Journal of Wildlife Management*, *80*(3), 387-395.

Rogala, J. K., Hebblewhite, M., Whittington, J., White, C. A., Coleshill, J., and Musiani, M. (2011). Human activity differentially redistributes large mammals in the Canadian Rockies national parks. *Ecology and Society*, *16*(3), 17. https://doi.org/10.5751/ES-04251-160316

Scholten, J., Moe, S. R., and Hegland, S. J. (2018). Red deer (*Cervus elaphus*) avoid mountain biking trails. *European Journal of Wildlife Research*, *64*(1), 1–9.

Seip, D., Johnson, C., and Watts, G. (2007). Displacement of mountain caribou from winter habitat by snowmobiles. *The Journal of Wildlife Management, 71*(5), 1539-1544.

Shartaj, M. and Suter, J.F. (2020). Exploring the Local Determinants of Campground Utilization on National Forest Land. *In Western Economics Forum*, 18(2), 114-128.

Shively, K. J., Alldredge, A. W., and Phillips, G. E. (2005). Elk reproductive response to removal of calving season disturbance by humans. *The Journal of Wildlife Management*, *69*(3), 1073–1080.

Sibbald, A., Hooper, R., McLeod, J., and Gordon, I. (2011). Responses of red deer (*Cervus elaphus*) to regular disturbance by hill walkers. *European Journal of Wildlife Research,57*(4), 817-825.

Siikamäki, J. (2009). Use of time for outdoor recreation in the United States, 1965–2007. RFF Discussion Paper No. 09-18, Available at SSRN: https://ssrn.com/abstract=1408690 or http://dx.doi.org/10.2139/ssrn.1408690

Skagen, S., Knight, R., and Orians, G. (1991). Human disturbance of an avian scavenging guild. *Ecological Applications, 1*(2), 215-225.

Sato, C. F., Wood, J. T., and Lindenmayer, D. B. (2013). The effects of winter recreation on alpine and subalpine fauna: a systematic review and meta-analysis. PloS One, 8(5), e64282.

Spaul, R., and Heath, J. (2016). Nonmotorized recreation and motorized recreation in shrub-steppe habitats affects behavior and reproduction of golden eagles (*Aquila chrysaetos*). *Ecology and Evolution, 6*(22), 8037-8049.

Spaul, R., and Heath, J. (2017). Flushing responses of golden eagles (*Aquila chrysaetos*) in response to recreation. *The Wilson Journal of Ornithology, 129*(4), 834-845.

Sproat, K., Martinez, N., Smith, T., Sloan, W., Flinders, J., Bates, J., Bleich, V. (2019). Desert bighorn sheep responses to human activity in south-eastern Utah. *Wildlife Research (East Melbourne), 47*(1), 16-24.

Steven, R., Pickering, C., and Castley, J. G. (2011). A review of the impacts of nature-based recreation on birds. *Journal of environmental management*, *92*(10), 2287-2294.

Squires, J. R., Olson, L. E., Roberts, E. K., Ivan, J. S., and Hebblewhite, M. (2019). Winter recreation and Canada lynx: reducing conflict through niche partitioning. *Ecosphere*, *10*(10), e02876.

Stalmaster, M., and Newman, J. (1978). Behavioral responses of wintering bald eagles to human activity. *The Journal of Wildlife Management, 42*(3), 506-513.

Stankowich, T., and Coss, R. G. (2006). Effects of predator behavior and proximity on risk assessment by Columbian black-tailed deer. *Behavioral Ecology*, *17*(2), 246-254.

Stankowich, T., and Coss, R. G. (2007). Effects of risk assessment, predator behavior, and habitat on escape behavior in Columbian black-tailed deer. *Behavioral Ecology*, *18*(2), 358-367.

Stankowich, T. (2008). Ungulate flight responses to human disturbance: a review and meta-analysis. *Biological conservation*, *141*(9), 2159-2173.

Steenhof, K., Brown, J., and Kochert, M. (2014). Temporal and spatial changes in golden eagle reproduction in relation to increased off highway vehicle activity. *Wildlife Society Bulletin, 38*(4), 682-688.

Steidl, R., and Anthony, R. (2000). Experimental effects of human activity on breeding bald eagles. *Ecological Applications, 10*(1), 258.

Stinson, D. W. 2001. Washington state recovery plan for the lynx. Washington Department of Fish and Wildlife, Olympia, Washington. 78 pp. + 5 maps.

Stinson, D. W. 2021. Periodic status review for the greater sage-grouse in Washington. Washington Department of Fish and Wildlife, Olympia, Washington. 20+ iv pp.

St-Louis, A., Hamel, S., Mainguy, J., and Côté, S. D. (2013). Factors influencing the reaction of mountain goats towards all-terrain vehicles. *The Journal of wildlife management*, *77*(3), 599-605.

Sunde, P., Stener, S. Ø., and Kvam, T. (1998). Tolerance to humans of resting lynxes (*Lynx lynx*) in a hunted population. *Wildlife biology*, *4*(3), 177-183.

Sweanor, L., Logan, K., Bauer, J., Millsap, B., and Boyce, W. (2008). Puma and human spatial and temporal use of a popular California state park. *The Journal of Wildlife Management, 72*(5), 1076-1084.

Switalski, A. (2016). Snowmobile best management practices for Forest Service travel planning: a comprehensive literature review and recommendations for management. *Journal of Conservation Planning*, *12*, 1-7.

Switalski, A. (2018). Off-highway vehicle recreation in drylands: A literature review and recommendations for best management practices. *Journal of Outdoor Recreation and Tourism*, *21*(May 2017), 87–96.

Taylor, A. R., and Knight, R. L. (2003). Wildlife responses to recreation and associated visitor perceptions. *Ecological applications*, *13*(4), 951-963.

Tyler, N. (1991). Short-term behavioural responses of Svalbard reindeer (*Rangifer tarandus platyrhynchus*) to direct provocation by a snowmobile. *Biological Conservation,56*(2), 179-194.

United States Fish and Wildlife Service - Caribou. (n.d.). Retrieved March 15, 2022, from https://www.arcgis.com/apps/mapviewer/index.html?layers=bc69ac34e3a24d8aabe55dd84d9a8bafandlayerId=0

VanDyke, W. A., A. Sands, J. Yoakum, A. Polenz, and J. Blaisdell (1983). Wildlife habitats in managed rangelands-the Great Basin of southeastern Oregon. Bighorn Sheep. General

Technical Report. PNW-159. Pacific Northwest Forest and Range Experiment Station. U. S. Department of Agriculture. Forest Service. 37pp.

Wang, Y., Allen, M., and Wilmers, C. (2015). Mesopredator spatial and temporal responses to large predators and human development in the Santa Cruz Mountains of California. *Biological Conservation, 190*, 23-33.

Western Wildlife Outreach - Mountain Lions (n.d.). *Discover Washington's Cougars.* Retrieved March 15, 2022, from https://wdfw.wa.gov/sites/default/files/2019-03/Cougar%20Brochure.pdf

Washington Department of Fish and Wildlife - Wolverines. (n.d.). *Wolverines*. Retrieved March 15, 2022, from https://wdfw.wa.gov/species-habitats/species/gulo-gulo-luscus

Washington Geospatial Open Data Portal - Wolves. (n.d.). Retrieved June 1, 2022, from https://geo.wa.gov/datasets/wdfw::wolf-pack-polygons-all-years/explore?location=46.737207%2C-117.941131%2C6.89

Washington Department of Fish and Wildlife - Wolves. (n.d.). *Wolves in Washington*. Retrieved March 15, 2022, from https://wdfw.wa.gov/species-habitats/at-risk/species-recovery/gray-wolf/history

Washington Wildlife Habitat Connectivity Working Group (WHCWG). (2010). Washington Connected Landscapes Project: Statewide Analysis. Washington Departments of Fish and Wildlife, and Transportation, Olympia, WA.

Watson, J. W. (2004). Responses of nesting bald eagles to experimental pedestrian activity. *Journal of Raptor research*, *38*(4), 295-303.

West, E. H., and Peery, M. Z. (2017). Behavioral mechanisms leading to improved fitness in a subsidized predator. *Oecologia*, *184*(4), 787-798.

Westekemper, K., Reinecke, H., Signer, J., Meißner, M., Herzog, S., and Balkenhol, N. (2018). Stay on trails – effects of human recreation on the spatiotemporal behavior of red deer Cervus elaphus in a German national park. *Wildlife Biology*, *2018*(1).

Wiedmann, B., and Bleich, V. (2014). Demographic responses of bighorn sheep to recreational activities: A trial of a trail. *Wildlife Society Bulletin, 38*(4), 773-782.

Wiles, G. J., H. L. Allen, and G. E. Hayes. (2011). Wolf conservation and management plan for Washington. Washington Department of Fish and Wildlife, Olympia, Washington.

Williams, S. and Moskowitz, D. (2020). 2020 Cascades Wolverine Project progress report. Retrieved from www.cascadeswolverineproject.org

Wisdom, M. J., Ager, A. A., Preisler, H. K., Cimon, N. J., and Johnson, B. K. (2004). Effects of off-road recreation on mule deer and elk. *In: Transactions of the 69th North American Wildlife and Natural Resources Conference: 531-550*.

Wisdom, M.J., Preisler, H. K., Naylor, L. M., Anthony, R. G., Johnson, B. K., and Rowland, M. M. (2018). Elk responses to trail-based recreation on public forests. Forest Ecology and Management, 411, 223–233.

Wolfe, S., Griffith, B., and Wolfe, C. (2000). Response of reindeer and caribou to human activities. *Polar Research, 19*(1), 63-73.

Wynn-Grant, R., Ginsberg, J. R., Lackey, C. W., Sterling, E. J., and Beckmann, J. P. (2018). Risky business: Modeling mortality risk near the urban-wildland interface for a large carnivore. *Global Ecology and Conservation*, *16*, e00443.

APPENDIX A

This table highlights possible conservation implications drawn from each of the species accounts in this report, along with each species' Washington State conservation status (WA Status). Wildlife managers and conservationists can consider possible implications when formulating plans to mitigate potential negative impacts of recreation to wildlife populations. We recommend implementing any management or conservation actions using an adaptive management framework and carefully considering the context from which all possible implications were drawn. Page number for each species account "Implications" section is listed next to the species name. LC= Least Concern, EN= Endangered, SGCN= Species of Greatest Conservation Need (under the Washington State Wildlife Action Plan), PS= Priority Species (under the Washington Priority Habitats and Species Program).

Species	WA Status	Possible Implications
Bighorn sheep (p. 11)	SGCN	• Disturbance during the lambing season may entirely displace reproducing females from high quality habitat and lead to a decrease in reproduction success. For areas where high levels of recreation in Washington overlap with lambing habitat, managers could consider seasonal closures. • Areas of overlap between winter recreation and sheep wintering areas should be identified. Restricting recreation in these areas could be considered to mitigate the risk of displacing sheep from winter habitat. • Activity at elevations above sheep is more disturbing than below, and nearby escape terrain is essential for sheep, especially females with young. Consider restricting off-trail travel in important sheep habitat, and protecting easily accessible, high-quality escape terrain for sheep by directing trails away from these areas.

Caribou (p. 16)	EN	• Caribou are especially sensitive to recreation during the calving season, when the risk of energetic expenditures in response to disturbance are highest. Consider a buffer distance of at least 350 m from caribou during this time. • Caribou are highly disturbed by less predictable forms of recreation (off-trail, quiet). Encourage on-trail use and use of trail systems that are already established versus expanding trail systems. • Where new trails are necessary, consider building in low-elevation terrain such as valley bottoms. • Caribou are easily displaced by snowmobiles, resulting in the loss of access to high-quality habitat and potentially increasing mortality risk. Consider restricting use of snowmobiles in and adjacent to high-quality caribou habitat.
Elk (p. 21)	LC	• Female elk are especially sensitive to recreation during calving season, when repeated disturbances can lead to decreased calf production. Important elk calving grounds that overlap with recreation should be identified and visitation could be limited during this time of year to reduce the risk of lowered calving rates. • Consider enforcing trail guidelines (e.g., limiting off-trail travel, discouraging direct approach of elk) in important elk habitat during sensitive times of year. • Create visual or spatial buffers between foraging areas and recreation corridors. • Elk will shift activities temporally to avoid recreation, thus protecting refugia during crepuscular and nocturnal hours is especially important. Consider instating seasonal and/or nighttime closures where appropriate to provide elk with refuge from disturbance.

Mountain goat (p. 26)	PS	• Recreation can have particularly negative effects on mountain goats who specialize on narrow bands of habitat with limited areas to seek refuge. Thus, backcountry recreationists should stay 1,500 m from goats to minimize disturbance and managers should consider routing trails away from mountain goat winter range, kidding areas, and mineral licks. • Mountain goats are negatively impacted by the sound of helicopters and do not appear to habituate to this disturbance. Consider identifying areas where goats are subject to higher levels of helicopter use and implementing restrictions to reduce the risk of disturbance in these areas. • ORVs have a negative effect on mountain goats, especially when moving faster and directly towards goats. ORV users should be discouraged from directly approaching mountain goats and should reduce their speed.
Mule deer (p. 32)	PS	• Motorized and non-motorized recreation can cause disturbance in wintering areas. Consider restricting both motorized and non-motorized recreation on important wintering grounds. • In areas where nighttime recreation is increasing, nocturnal closures to recreation could be considered, especially during sensitive times of year since mule deer can adjust their diel patterns to reduce temporal overlap with humans. • Recreation plans that overlap with mule deer habitat should strive to consolidate their footprint to preserve available spatial refugia. • Mule deer can somewhat habituate to regular and predictable on-trail recreation but have stronger responses to off-trail recreation and to dogs. Consider encouraging or restricting recreation to remain on-trail and requiring dogs to be leashed during sensitive times of year and in important deer areas.

Black bear (p. 36)	LC	• Black bears can maintain territories with high recreational use, but will alter both their behavior and movement patterns to avoid encountering humans. On trails with high recreational use, black bears can be both spatially and temporally displaced, using trails less and shifting to more nocturnal activity patterns. Maintaining both spatial and temporal refugia into which bears can shift their activity can help mitigate bear displacement. When land managers are evaluating proposals for future recreational development it is important to identify areas of spatial refugia for protection from increased recreation. Temporal refugia can be maintained by restricting use of recreational areas to daytime hours when human activity is already highest. • Recreation may have indirect effects on black bear population dynamics, including 1) increased mortality risk from vehicle collisions if animals are displaced from trails or forced to cross roads to avoid recreation and 2) human-black bear conflict. Identifying and avoiding recreational development across important wildlife travel corridors should be considered when planning new recreational areas. Implementing measures to secure anthropogenic foods and garbage at campgrounds and trailheads can mitigate human-bear conflict. • Denning is a sensitive time for bears where disturbance can cause abandonment of dens and cubs. To mitigate disturbance in important denning areas, winter recreation should be restricted.
Canada lynx (p. 42)	EN	• Development of ski resorts in Washington could cause fragmentation and loss of habitat for lynx and should thus be carefully considered to minimize potential impacts to lynx. • Recreation levels should be assessed in popular areas that overlap with core lynx habitat. Areas where winter recreation levels are high could act as targeted areas to monitor for continued lynx occupancy or for implementing recreation management actions, such as visitor limitations. • Depending on snowpack density, snowmobile trails may facilitate coyote use of lynx habitat in winter which could increase competition for snowshoe hares. Therefore, consider limiting the spatial extent of snowmobile trail networks in lynx range, especially in important hunting habitat, to reduce the potential risk of competition for prey between coyotes and lynx.

Grizzly bear (p. 47)	EN	• Grizzly bears may shift activity to more nocturnal behavior and avoid areas of high human activity in response to recreation. Maintaining both spatial and temporal refugia into which bears can shift their activity can help mitigate bear displacement. When land managers are evaluating proposals for future recreational development it is important to identify areas of spatial refugia for protection from increased recreation. Temporal refugia can be maintained by restricting use of recreational areas to daytime hours when human activity is already highest. • Grizzly bear displacement is of greatest concern during periods of hyperphagia and denning. Non-motorized trails should be planned to avoid areas of high natural food abundance where possible. • Summer motorized recreation has consistently strong, negative effects on grizzly bears. Reducing road densities through important grizzly areas by decommissioning select roads and limiting the construction of new roads can help support bear populations in these areas. • Backcountry skiing and heli-skiing activities can overlap with prime bear denning locations and can cause bears to abandon den sites; consequences are greatest for reproductive female bears. Areas of overlap between winter recreation and high-quality denning habitat should be identified and seasonal closures can be implemented in these areas to avoid disturbance. • More research is needed to better understand the winter soundscapes that motorized recreation can create and how they may impact denning bears.

Mountain lion (p. 52)	LC	• Mountain lions are displaced in areas that allow recreation, with abundance decreasing as recreation increases. In areas of high-quality mountain lion habitat, managers could consider limiting visitation. • Nocturnality helps mountain lions avoid recreation temporally without shifting spatially, but lions will still alter diel patterns to consolidate morning and evening activities to nighttime. In areas where high levels of recreation overlap with high-quality mountain lion habitat, managers could consider instating dusk to dawn trail closures. • Allowing dogs to accompany recreationists in mountain lion habitat may increase the number of users in these areas, leading to a possible decrease in mountain lion space use and abundance. Consider restricting dogs in areas of important mountain lion habitat. • Educate the recreational public about mountain lion ecology and their use of recreational trails to mitigate human-lion conflicts.
Wolf (p. 57)	EN	• Wolves are highly sensitive to increasing road densities. Reducing road densities through important wolf habitat by decommissioning select roads and limiting the construction of new roads can help support wolf populations in these areas. • Human activity causes wolves to avoid areas within a 400 m buffer of trails. Therefore, maintaining spatial refugia for wolves in areas with non-motorized recreation trails may be important. Recreation planners can consider constructing compact trail networks to avoid fragmentation of important wolf habitat, such as areas with low road densities, high prey availability, and those in close proximity to known den and rendezvous sites. • There is mixed, yet limited evidence of recreational impacts on wolves; both neutral and negative responses were documented. Additional research is needed to understand how increasing trail densities impact wolf use.

Wolverine (p. 62)	SGCN	• Wolverines, and especially reproductive females, are sensitive to recreational disturbance and most affected by dispersed and off-road winter activities, such as snowmobiling and backcountry skiing. To mitigate non-motorized disturbance, land managers can consider limiting off-trail travel in important habitats, additional groomed access points, and heli-skiing areas. To mitigate motorized disturbance, consider limiting further winter motorized access to important wolverine habitat to preserve spatial refugia. In addition, the relative footprint of a given activity (motorized and non-motorized) is a key consideration for wolverines. • Further research should be conducted to understand the extent to which wolverines are impacted by noise associated with motorized travel. • Little is known about potential summer recreation impacts to wolverines. Further research is needed on the effects of dispersed, off-trail summer travel on wolverines.
Bald eagle (p. 67)	SGCN	• Eagles are especially sensitive to disturbance during nesting season. Spatial buffers of 500 m or more should be established between eagle nest sites and recreation activities. Larger, secondary buffers of 1,200 m could reduce impacts of more disturbing activities on nesting eagles. • Limit recreational opportunities in high-quality nesting, feeding, and overwintering habitat to protect the majority of eagles in a given population. • Visual screening (vegetation, topography, man-made structures) are important factors in limiting the impacts of disturbance to eagles. Maintain trees above 40 m in height and preserve other types of vegetative cover along existing recreation corridors to serve as screening, especially in the absence of a spatial buffer. • High-quality feeding and overwintering habitat may be protected outside of the nesting season by instating spatial buffers of 75 m-250 m from recreation activities.

Golden eagle (p. 71)	SGCN, PS	• Eagles are vulnerable to disturbance during the nesting season. Consider performing an inventory of Washington's nest sites and implementing seasonal closures in nesting areas or developing spatial buffers between recreational travel routes, infrastructure, and nest site areas. • Eagles are especially vulnerable to disturbance in the early nesting season; prioritize management actions in the early nesting season and in areas with abundant recreational access points.
Marbled murrelet (p. 76)	EN	• Nest predation by corvids poses a significant threat to murrelets. Corvid abundance, and perhaps predation of murrelet nests, can be elevated in and around campgrounds since these sites provide anthropogenic food subsidies. Education at campgrounds on the importance of securing food and installing animal-proof garbage cans may help to lower the value of campgrounds to corvids and reduce their local abundance. • For new campground development, consider limiting and concentrating them near existing anthropogenic food sources to contain the spread of corvid "hot spots" into other, relatively pristine forests important to nesting marbled murrelets.
Sage grouse (p. 81)	EN	• Where areas of overlap between recreation and sage-grouse habitat are identified, off-road motorized recreation should be restricted to protect sage plants, prevent the spread of invasive weeds, and reduce the risk of fire ignitions. • Breeding and nesting seasons are a particularly sensitive time; lek sites are easily disturbed. Thus, protecting breeding sage-grouse from visual and auditory disturbance by motorized recreation is important. In addition, hikers, bikers, wildlife viewers, and photographers should be restricted around leks during the breeding season.