Berger – Bighorns and Recreation

Annual Performance report for reporting period: 1/01/2024 to 12/31/2024

Public Land Recreation and Desert Bighorn Sheep

Blending Empiricism with Bio-Energetic Models to Predict Disturbance Costs during Late Gestation Critical Periods

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Contents

Project Summary

The Colorado Plateau covers ~150,000 mi^2 across parts of Utah, Arizona, Colorado, and New Mexico. Approximately 50% is public land where an estimated 40 million tourists visited in 2023 (*AI generated value*) with a subset of about 4-5 million recreating in southeast Utah. Tourism drives local economies but also impacts wildlife. As a consequence, this project focused on a species of bio-cultural importance which likewise is an iconic representative of southwestern ecosystems – desert bighorn sheep. The broader question: *What are the biological impacts of different types of recreation on desert bighorn sheep?*

To address this question, data were gathered on wild bighorn populations; more specifically on pregnant females in their last trimester which is in early spring. This period coincides with important intrinsic and extrinsic events – biological needs for protein which support exponential fetal growth, spring emergence of nitrogen-rich plants, and a time of year when the bulk of recreationists are in bighorn habitats.

The study involved three BLM areas in Southeastern Utah (Moab, the Northern San Rafael Swell, and the Southern San Rafel Swell) where sheep also moved in and out of three protected parks (Canyonlands and Arches; and Dead Horse State Park). Comparative, experimental, and observational techniques were employed for both GPS collared and non-collared bighorns. Comparisons involved sites of high, medium, and low recreation; experiments broadcasted familiar neutral sounds (raven) and those of people yelling and motorcycles to female bighorns, and contrasts of sheep responses when exposed to motorized and non-motorized recreationists. Observations were systematic and ad hoc to capture the full range of sheep foraging and flight responses under the above conditions. Among external variables assessed were distances to different types of roads, habitat use and sheep activity cycles during high and low periods of recreational disturbance, and impacts of differential types of recreation (bicycles, motorcycles, hikers, all-terrain vehicles).

Preliminary results (below) carry the necessary caveat they may change as sophisticated analyses proceed and account for differences in sampling intensity and variation. Current findings suggest: 1) <u>Energy expenditures</u> ~5-10X> among non-habituated sheep in response to disturbance than those with greater familiarity to humans. Context, however, markedly affected local site abandonment and flight; 2) <u>Roads</u> (graveled and paved) tended to be avoided, and sheep respond more intensely when disturbed near roads of a sinuous nature. Sheep were 4-6 times less abundant in areas heavily traversed with 4-wheeled drive vehicles when compared between two adjacent canyons with a similar food base. 3) <u>Sounds</u> of motorcycles had stronger negative effects on foraging rates than those of hiking humans, though results are based on small samples sizes. 4) <u>Low flying helicopters</u> regularly disturbed bighorns, causing serious long flight distances and habitat abandonment.

Across the last four years, a total of 18 lectures were delivered to audiences from local stakeholders and government and to the public, at universities, and at national and international levels. Seven podcasts aired, media coverage of the recreation-wildlife divide was expanded, and several scientific publications in peer-reviewed journals were distributed. A No-Cost Extension of this project is pending to enable the robust sorts of complex analyses required to develop scientifically defensible results.

Backdrop and Objectives

'The Why' – Commencing in 2020, Colorado State University initiated a formal study with funding from Bureau of Land Management State University to address issues concerning how changing (increasing) levels of recreation on public lands affect bighorn sheep in SE Utah. Public lands are of unique value for both recreation and economy. In 2015, nearly 7.5 million visitors used Utah BLM lands; in 2022 that number increased nearly 50% to ~11+ million. Tourism-related use of public lands generated about $525 million to state revenue in 2015; in turn almost 5,000 jobs were supported (BLM-UT 2019).

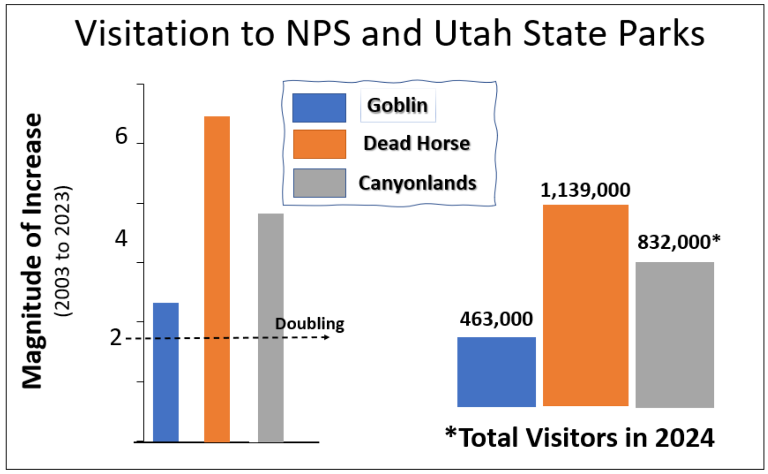


Fig. 1. Relationships among time (decade) and relative magnitude of increase in visitors (NPS, Utah State Park data) and total visitation in 2024.*Y axis* reflects increase through 2023 because NPS data are incomplete for *2024 calendar year and reflect only into autumn.

Within this period, wildlife-associated recreation contributed just over $100 million and supported more than 15% of the above Utah jobs (Pew Trust 2018). While tourism-based recreation greatly enhances economies and especially gateway communities, much remains unknown about the impacts to wildlife of diverse and growing recreation on Utah BLM lands.

At Dead Horse State Park for instance there has been a 6-fold increase in attendance across two decades; at Canyonlands National Park an approximate quadrupling (Fig.1). How such visitation intersects with the biological needs of sensitive and iconic wildlife is not well known. Filling such knowledge gaps is particularly important for the management and conservation of species of high investment – including especially those of high bio-cultural value – such as Utah's only native persisting desert bighorn sheep (*Ovis canadensis nelson*). Bighorns remain the most featured animal in rock carvings which is demonstrative of a long-term recognizable bio-cultural icon (Fig. 2; also, Berger 2023).

Fig. 2. Desert bighorn sheep petroglyph.

'The What' – A variety of disturbances has been associated with interactions between people and bighorns. These vary from 'no response' to humans (which is rare) during feeding, to interruptions that include vigilance, walking away, flight, and total site abandonment. Responses obviously depend on type, intensity, and frequency of disturbance (Fig. 3), and the willingness of individuals or groups to tolerate or escape, especially when nutritional needs are high. The intensity of these responses varies but can be understood through experimental manipulations of bighorns' recognition of their natural environment by manipulation of visual and sound cues (in the field; Fig. 4).

Current efforts are aimed at understanding the extent to which inadvertent human-stressors are incurred by bighorns during their last trimester of gestation. Nutritional needs and fetal growth increase exponentially during late winter and early spring, and this is also when more than 100,000 recreationists visit south- eastern Utah. Understanding the degree to which these putative competing realms (1-pregnant female nutritional needs, and 2- recreational visits) intersect and impact desert bighorn sheep is the central focus of this continued research.

Fig. 3. Flight (top) and alarm (bottom); in most cases the interactants are not in the same frame because sheep flee.

'The How' – To address questions about the nature of effects on female bighorns, my team and I have been focused on three broad study regions – each varying in the type and magnitude of recreation.

The three study regions cover about 5,700 km^2 including two geographically (mostly) separated herds exclusively on BLM lands within the northern and southern parts of the San Rafael Swell. The 3rd study site is the Potash area (Moab realm) including parts of Arches and Canyonlands National Parks and adjacent BLM lands (Fig. 5).

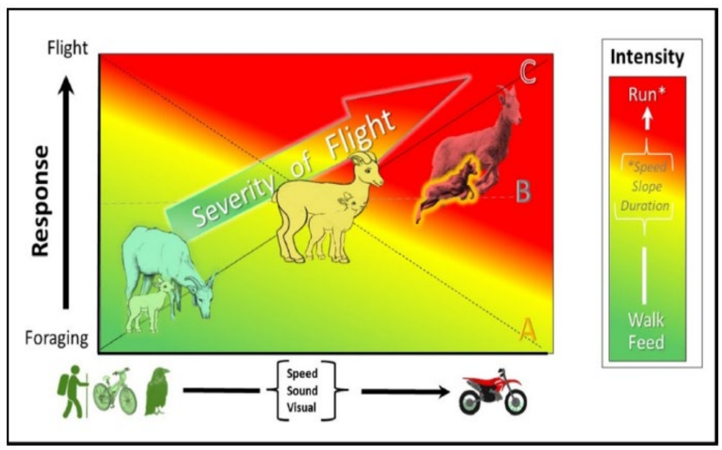


Fig. 4. Schematic of intensified (green to red) energetically costly responses to stimuli in Utah, USA, with feeding being a net energy gain and flight across steep terrain at high speeds being the costliest. Types of possible disturbance illustrated on the x-axis; A–C reflect hypothesized differential responses. Included are raven as a neutral stimulus. Intensity can be measured by relative expenditures of joules and refined by knowledge of durational use of slope and speed of travel (Berger and Cassidy 2024).

Visitation to these three sites has increased annually (Fig. 6) with spring the period of greatest visitation. For ease of presentation, types of recreation are classified as either motorized or non-motorized activities using spot checks across diurnal periods. For the purposes of this report, motorized vehicles are classified as to type and lumped (Fig. 6) and include SUVs, side-by-sides, spiders, motorcycles, jeeps, trucks, and vans. Non-motorized refers to mountain bikes, hikers, and horse-back riders. Rarely is it possible to determine from a distance whether bicycles are eBikes or not, and the latter are lumped with mountain biking; in most cases (>90% when in proximity it is obvious if a bicycle is electric or not). Among the variables contrasted among study areas to develop insights into sheep responses are the frequency, type, and magnitude of exposure to human presence coupled with types of recreational activity.

The Project and Progress.

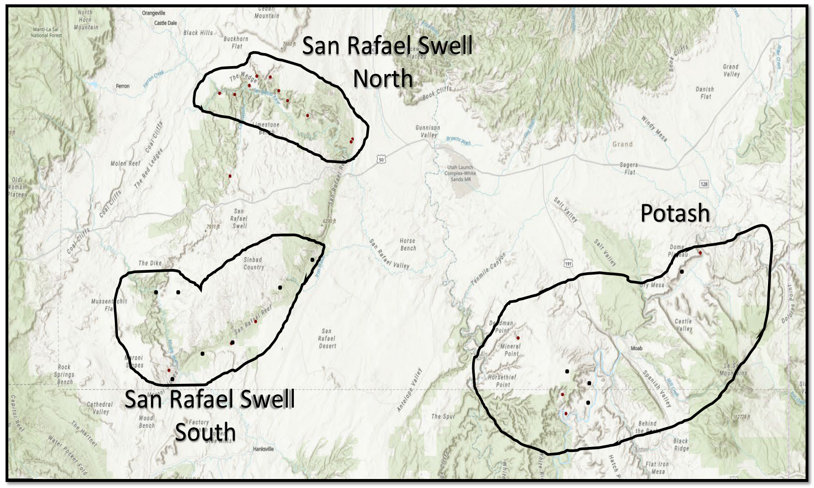
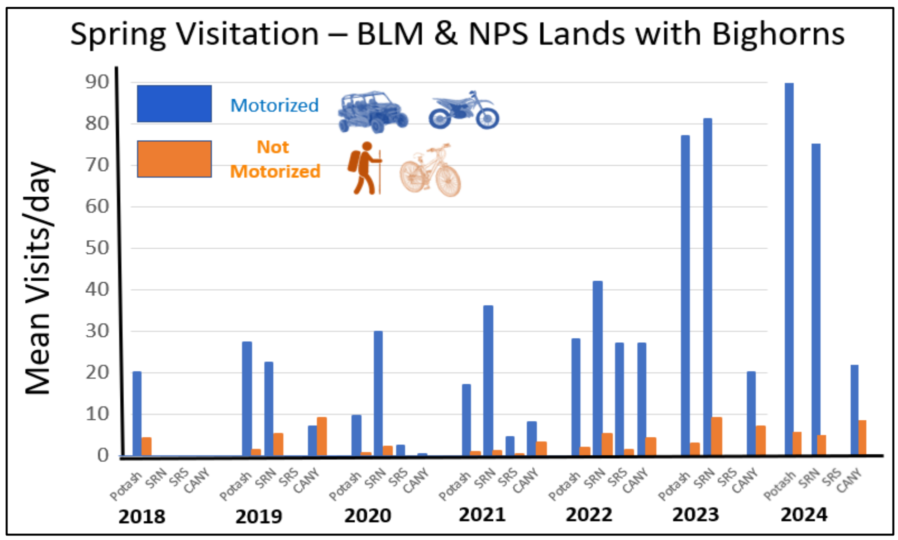


Fig. 5. Study regions in SE Utah. Dots reflect individually known females between 2021-2023.

<u>Preamble</u> – Among the major aims of this research is to expand upon prior studies of disturbance in bighorn sheep. Whereas recent studies use GPS data and derive inferences based on resource selection functions, direct observations have been unavailable to explore sheep responses. Consider by way of example GPS data across a 30-day period. The average movement of a female sheep on a per day or per week will offer values with a mean, a variance, and a date-time stamp. Additional variables would also include weather, habitat, and distance to nearest road. A useful variable that also is frequently included as an index of potential food is the Normalized Difference Vegetation Index (NDVI), which is essentially a measure of spectral conditions for which vegetation greenness is quantified and then used to map vegetation density.



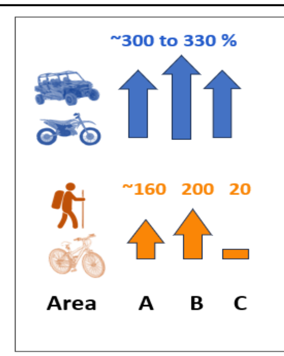


Fig. 6. (Top) A) Summary of visitation by category into four separated study areas as follows: Potash, SRN – San Rafael Swell North, SRS – S. R. Swell South, and CANY - Canyonlands. (Bottom) Percent relative change using 2019 baseline values; study areas (respectively) 'A", "B", "C" are San Rafel Swell (combined), Potash, Canyonlands.

Most analytical approaches of these sorts then model what is considered 'normal' in relation to movements that deviate using a probability distribution which is matched against a random one. If 90% of the points were clustered for instance but a few then were comprised of long-distance movements, it would not be possible to assess whether the long-distance movements were normal on a periodic basis, <u>*or*</u>, alternatively, if they were provoked by 1≥ disturbance events.

Many external and intrinsic factors will affect behavioral decisions of individuals or groups such as the need for critical resources, and whether to flee or feed, among others. Group size is one that has well known impacts on foraging decisions just as might road traffic, hikers, ravens, or aircraft. Insights on whether such factors may play a role, such as the illustrated long-distance flight after disturbance to two jeeps (Fig. 7). These could not have realistically deduced from GPS data alone in the absence of knowing a causal basis.

Real time movements of GPS points are reflected in an actual linear pathway (Fig. 7). While we

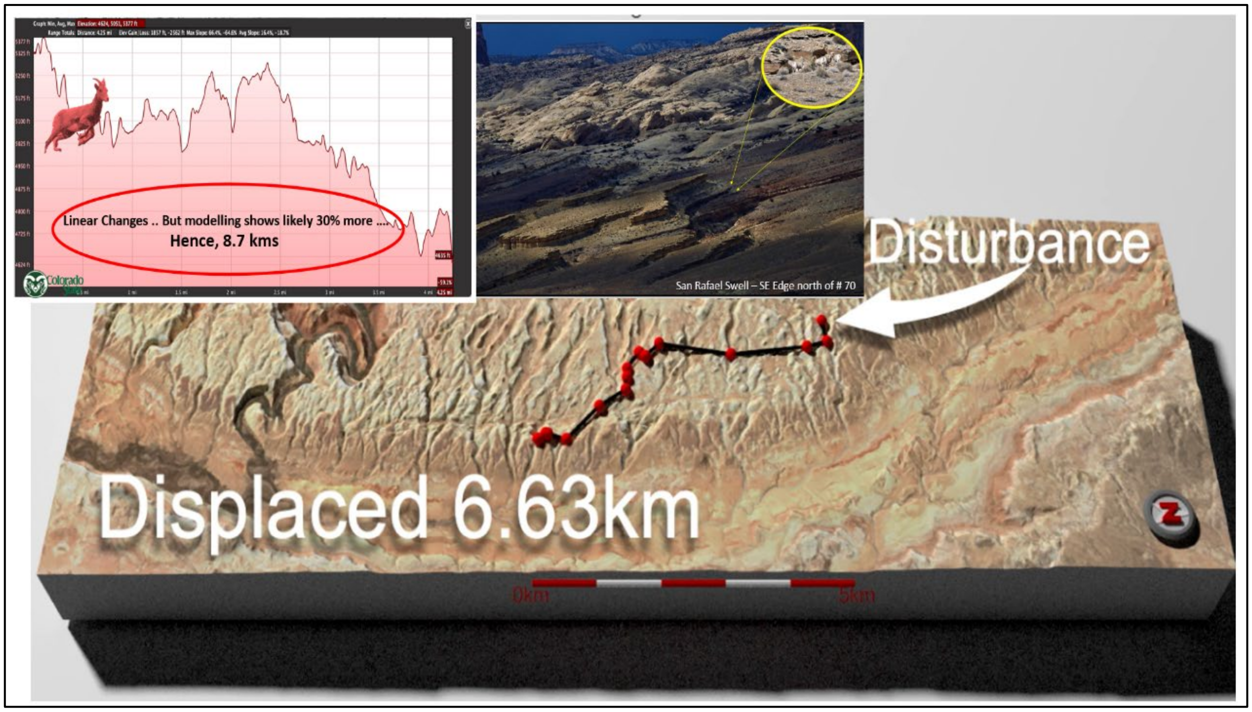


Fig. 7. Real time movements of a bighorn female in late March 2022; traverse is across east face of the San Rafael Rift. Insets: Left - elevation gradients navigated across duration of flight. Simulation and projection by F. Hayes, - Colorado State University; Center – site topography where disturbance occurred.

don't know the relationship between linear (straight line movement) to reality which would include hills, cliffs, and other components of a navigable route, if the variation was 30% between real and the plotted linear, then total flight distance would be about 8.7 kms (~5.2 miles).

Objectives and Explanations. – To increase insights beyond resource selection and movements, the current project is also reliant on direct observations. Some are ad lib observations of disturbance events (such as serious chasing by dogs of pregnant females with displacement more than three miles coupled with a failure to return to the traditional area (Fig. 8). Other observations are created by experimentally approaching bighorns on foot or on bicycles, and through exposure of auditory cues associated with humans and played through a speaker.

Hence, the primary objectives are to:

1) Understand the extent to which bighorns are responsive to human activity,
2) Quantify the frequency, intensity, and duration of disturbances by type,
3) Apply measures of physiological costs (caloric expenditures through estimation of joules spent) of locomotion and gestation in wild bighorn (this objective is described in the Supplementary Material from last year's progress report).

An essential component of meeting these objectives is assessment of potential for habituation. Non-habituated individuals are more likely to flee and to expend more calories if disturbed, and this is especially costly to females in late gestation (the range of possible responses is depicted in Fig. 4 in relation to different types of recreation).

Fig. 8. Plot of distance traversed and elevational change as a response of dogs chasing bighorns (Buckhorn Wash region of Northern San Rafel Swell.

<u>Data Collection</u> – We continue to gather information across all study areas by: 1) satellite downloads of locations of GPS collared females; 2) observations and experimental approaches to bighorns; and 3) ad hoc observations of bighorn responses to humans.

<u>Responses</u> – With respect to point 3, preliminary information is available on flight and its trajectories with group flights of considerable distances not being atypical. For instance, a post-disturbance flight in the Potash region covered 2.1 miles in eleven minutes, (Fig. 9 – image 'C').

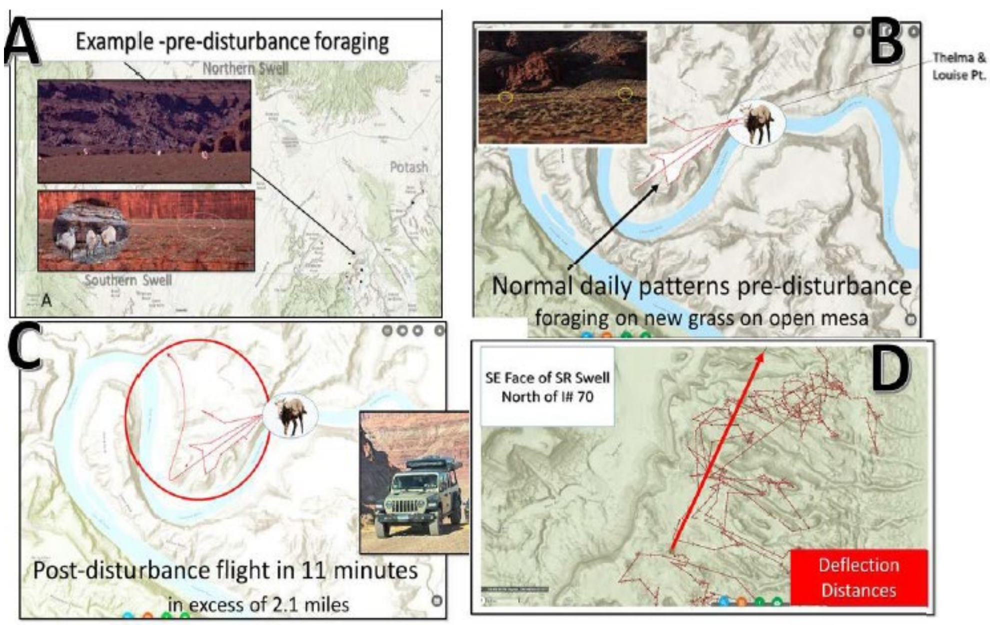


Fig. 9. Potash realm disturbance : A) Females feeding away from escape terrain; B) normal foraging patterns of non-disturbed sheep also illustrating feeding in flat terrain away from cliffs; stippled area is of minimum convex polygons of several prior days; C) displacement flight path (arching northwest in red circle) of same group from B when disturbed by a pod of vehicles; D) normal daily movements of female sheep (thin red lines); the thick line to the northeast shows the 4.6 mile flight trajectory in four hours. The circled sheep in A and B are visible if images are magnified to about 200%.

Examples of light, medium, and serious responses to vehicles are depicted in Figs 10-11). The first (Fig. 10) shows two curious yearlings as adults continue feeding. The second (Fig. 11), reflects stronger (but mixed) reactions along a road with high levels of sinuosity. Sound (decibel levels) are weaker and visual obstructions greater, which we are investigating to determine how these factors impact flight and foraging responses.

The final series (Figs. 11-13) illustrates evasive responses to a motorized group who then fled more than 600 meters when the animals could no longer be tracked.

Fig. 10.   A group of five bighorns; three adults foraging as bicyclists pass - White Rim Road in Canyonlands (2023).

Fig. 11. Bighorn group with flight and vigilance in Buckhorn Draw – Northern San Rafael Swell (2023).

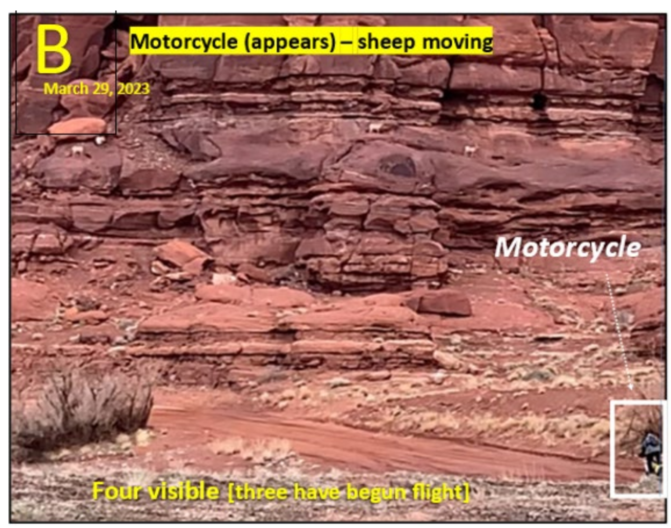


Fig. 12. A – Bighorns become vigilant to distant sound of motorcycles (not visible) about 400 m away; B – in flight as the motorcycle (far right bottom) appears (Potash Road, 2023).

Fig. 13. – Four sheep (four) are running even though the motorcycle has departed. The sheep are above the yellow dots.

Contrasts between Adjacent Canyons. – To enhance insights on broader overall recreational impacts, the abundance of sheep sign (tracks and scat samples) was contrasted between two adjacent canyons; 1) Long Canyon of primarily high daily levels of 4-WD vehicles (x = 41 ± 18.2) and the other (in popular vernacular), Owl Canyon with restricted public access (x = 1 ± 0.5) (Figs. 14,15). Each have water catchment sites at the upper ends, and north and south exposures were matched and standardized for elevational variation. Bighorn tracks were counted within three meters

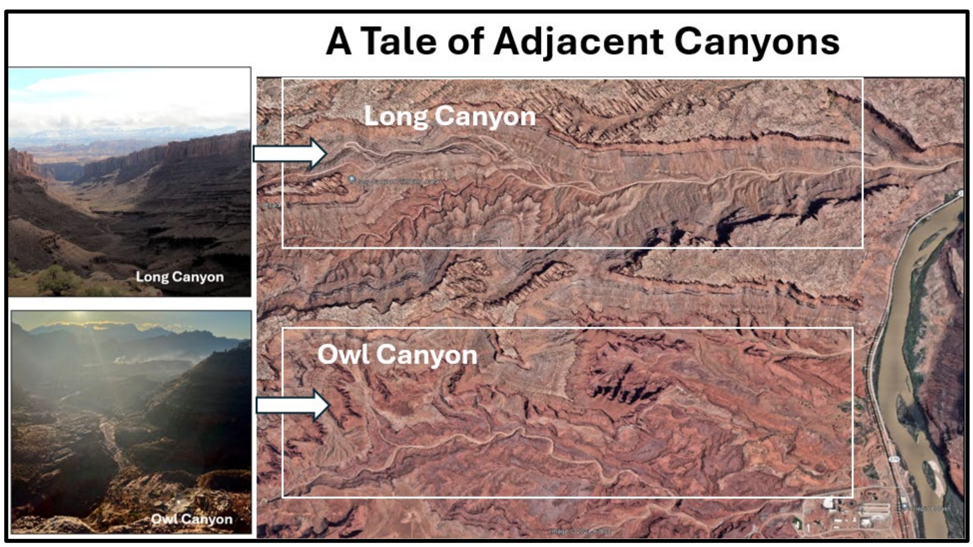


Fig. 14. Two accessible and adjacent canyons along Utah State Highway #279 bordering the Colorado River. Bottom right image is Potash Plant (Grand County, Utah), and (left) images of each canyon.

of each step taken that intersected predetermined 100-m walking transects. New grass emergence was counted using step-toe methodology (Berger 1991) for the same 100m transects and both tracks and grass recorded in April 2024. Vehicles counts/hour were averaged for March and April for daylight hours for each canyon (Fig. 15).

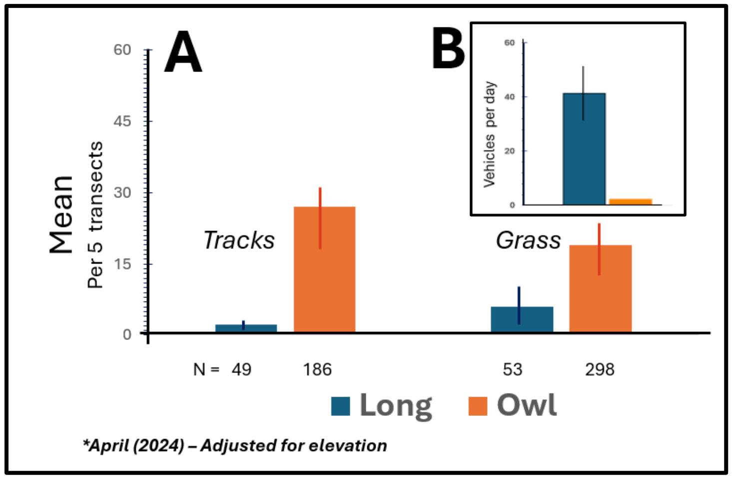


Fig. 15. A) Mean encounter rate/100 m transect of bighorn sheep tracks and emerged grass in Long and Owl Canyons. B) Mean daily vehicles between March 15 – April 15 (2024).

While some clear biases emerge when employing the above methods for indirect assessment of abundance – sheep, grass, and vehicle use as well as the recognition that heterogeneity exists between canyons – such contrasts hold some heuristic value to assess where sheep are most likely encountered. Of note and depending on different assumptions inherent in the methods used, bighorns in Owl Canyon are 4-6 times more likely to be encountered than in Long's Canyon; the latter on average had about 40 times more vehicles per day in the spring (Fig. 15).

<u>**Auditory Experiments and Responses to Playback Experiments**</u>. – In addition to developing data sets based on contrasts between canyons, geographical gradients, and experimental visual presentations and ad lib observations of responses by bighorns to disturbance, there continues to be growing interest to understanding potential impacts of noise. Hence, we are exposing foraging female bighorns to the standardized pre-recorded sounds of motorcycles and human voices. Those of ravens are used as a control because ravens are abundant and represent a non-threatening familiar sound. Although bighorns might react to a vehicle's speed and/or visual disturbance, our goal is exclusively to gather data on responses to noise. The playback experiments therefore are conducted to the extent possible when people are out of view. Our approach is arguably appropriate because in many places bighorns are exposed to auditory sounds but not the visual approaches of vehicles or people.

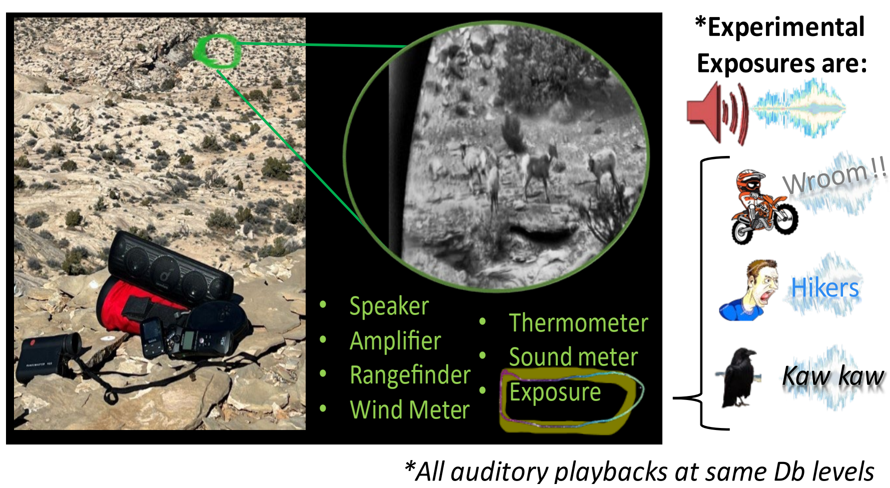


Fig. 16. – Overview of sound playback experiments. The image enlarged and circled in green are wild bighorns about 400 meters distant when exposed to sound playbacks. The types of auditory cues presented (motorcycle, raven, and human) are as indicated.

Measured responses include interruption of feeding, spacing between individuals, vigilance, group cohesion, clumping, and flight. Variables to be controlled by statistical models are distance to escape terrain, group size and composition, sex, distance between sheep and speaker (or vehicle), temperature, wind speed, and snow conditions.

Notably, responses among the study areas are to be contrasted to determine if exposure levels to recreationists vary; Potash having the most recreationists, San Rafael Swell-North as intermediate, and bighorns in the southwestern Swell least exposed (Fig 5).

Playback experiments adopt the following protocols. The duration of broadcasted sounds is set at 20 second pulses separated by 10 second intervals and continued for three series (e. g. 60 seconds of exposure). Behavioral responses are quantified for 180 seconds, both before, during, and after exposure with traits as below (Table 1).

Table 1 – Description of response of bighorn sheep to experimental playbacks of sound exposure and in the absence of of experimental cues (e. g. control).

Trait	Description
Feeding	self-evident, but the animal may also be walking with head in lowered position
Vigilant	head focused ahead, ears erect and staring
Clumping	when group members form a tight herd (photo); clumping is an indication that the group experiences perceived danger
Walking	evident; & when head high (above shoulders) suggests lack of focus on food
Fleeing	Heightened response: our measures will include steepness of slope, distance fled until out of view, and speed (based on gait)

Each acoustic stimulus is stored as a separate (audio) file as: (i) humans talking, (ii) four-stroke motorcycle with fluctuating sounds to reflect acceleration and steady state, and (iii) a raven (as mentioned, a control for a familiar, non-threatening animal sound). As a template for contrasts with ravens is the assessment of animal activity (e. g. feeding) when there is no exposure to any sounds. Decibel levels for all experiments are broadcast at 60–70 dB at 1 m from the speaker and levels identical for all experiments.

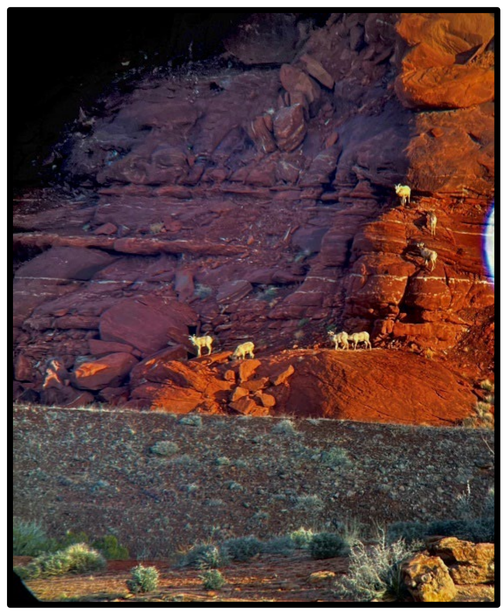


Fig. 17 – Example of sheep used as a control, with covariates of group size, distance to escape terrain (=0 m), and associated measures of green vegetation emergence (described and data in last year's progress report).

Preliminary (descriptive) analyses are based on 212 sound exposures to bighorns of which 60 were <225 m [Fig. 18*(A)*]. Because the sample sizes are limited, models have not yet been developed to parse out relative effects of different variables – in other words, only flight responses [Fig. 18 (*B*)] are displayed but show more than a three-fold probability of flight from motorcycle sounds than to those of human hikers or raven calls when within 225 m. Nevertheless, covariates as noted in Fig. 17 including potential effects of wind, temperature, topography, and distance to speaker must be considered as model development is enhanced with larger sample sizes.

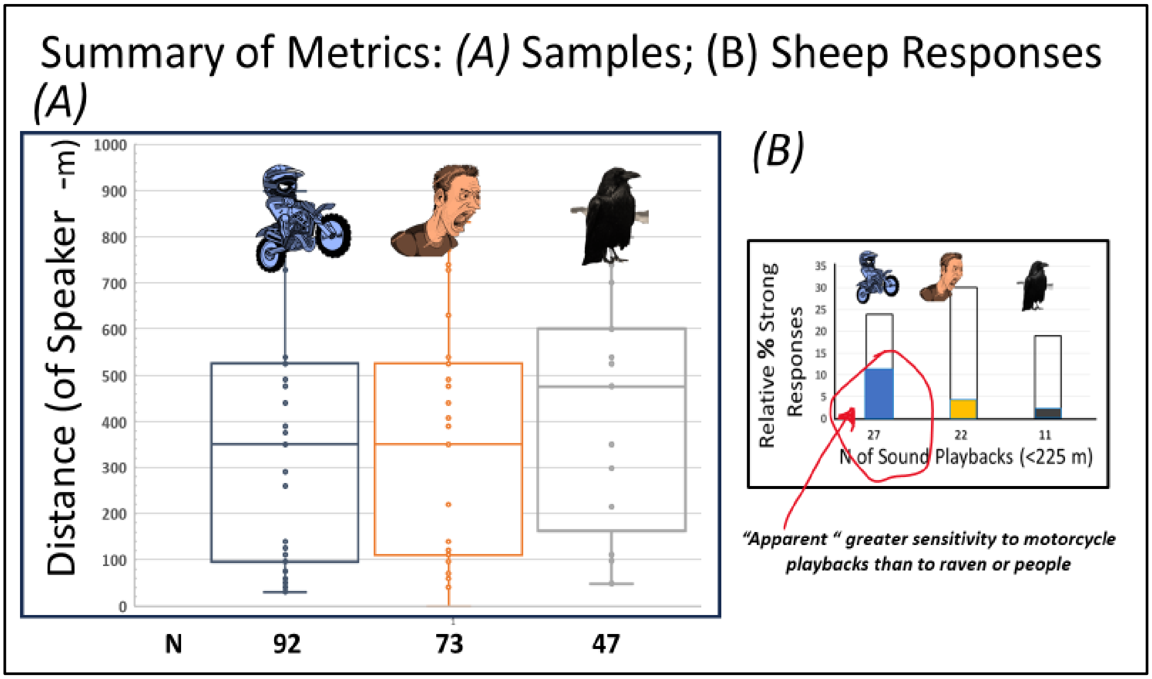


Fig. 18. – Descriptive statistics (A) of distance between sheep and speaker for sound experiments. (B) Colored bars are % occurrence of sheep flight responses relative to bar height; the blue suggests higher probability of fleeing from motorcycle sounds; Db level identical for all experiments. The height of histogram (bar) is the % of auditory playbacks within 225 m of the total sample (N) from (A). Strong sheep responses are operationally defined as those data bouts in which more than 50% of a group cease foraging for longer than 50% of a timed playback bout – responses could be clumping, walking, or vigilance, all of which precede serious flight.

Communication – Social Media, Talks, and Publications

Talks, podcasts, interviews, and other forms of current outreach are highlighted in images below and summed in two segments, 2021-2022 and 2023-2024. Of note, are six podcasts (one in 2022, three in 2023, and two in 2024). Thirteen public outreach events were delivered in 2023-2024. I also wrote an Op-ed/Commentary – published in the Salt Lake Tribune – as a call to heed bio-cultural respect by creation of a National Petroglyph with de facto recognition of desert bighorn or other animals of importance to Native Americans. And, Kira Cassidy and I published a paper in 2024," *Play is a privilege in both humans and animals: how our recreation influences wildlife*" J. of

Wildlife Management 2024;88:e22664 (https://doi.org/10.1002/jwmg.22664).

Lectures and podcasts, and outreach were as follows:

2021-2022

- Moab Outfitters Workshop (BLM – sponsored Moab; April)
- 8th Mountain Ungulate Conference (Italy – Oct)
- University of Colorado – Boulder (February)
- The Wildlife Society – Colorado Chapter (Fort Collins)
- Moab Science Public Lecture (December)

2023-2024

- National Public Lands Day (Sept – Grand Junction)
- Fort Lewis College (Sept - Durango)
- Canyonlands Natural History Association (January – Moab)
- BLM-NPS – Annual Stakeholders Meeting (March – Moab)
- University of Utah (Feb – Salt Lake City)
- Science-Moab Week (Sept- Moab)
- Texas A & M University (Oct – College Station)
- Moab (BLM) June presentation to Law Enforcement and Planning Staff
- New Mexico State University (Las Cruces)– Oct
- Kanab (BLM) – March
- Public Library of Kanab - March
- University of Utah (Feb – Salt Lake City)
- Canyonlands Natural History Association – (remote) November

Commentaries and Podcasts

- https://www.mammalwatching.com/podcast/
- https://soundcloud.com/user-495802209/human-noise-and-the-desert-bighorn
- https://podcasts.apple.com/kh/podcast/conserving-species-in-extreme-environments-dr-joel-berger/id858218890?i=1000588772007
- https://sciencemoab.org/studying-the-desert-bighorn/
- https://www.sltrib.com/opinion/commentary/2023/05/30/joel-berger-what-should-our/
- https://podcasts.apple.com/us/podcast/what-can-extreme-species-teach-us-about-survival-feat/id1643932767?i=1000669881417 What Can Extreme Species Teach Us About Survival?
- https://nationalparkstraveler.libsyn.com/national-parks-traveler-podcast-wildlife-at-play

Cooperation with Government Agencies.

I worked with Law Enforcement (Utah Department of Natural Resources) on wildlife harassment that involved dogs and helicopters chasing bighorns from critical habitats including along the Colorado River. Photo - work with a deputy examining maps of plots of harassment and disturbance. I'm also still collaborating with biologists from NPS, USGS, and – though not government – also local and regional NGOs.

2025 – Original Scope of Work

An explanation for a NCE (No Cost Extension of Funds) is hereby provided.

Justification.-

(1) *What work needs to be completed*? Two issues and solutions. A) Sample sizes need to be strengthened to develop stronger scientific inferences. This arises due to pseudo-replication (e. g. repeat sampling of some of the same individuals) because bighorn sheep are at low densities and some of the areas at two of the three study areas have been over-sampled. So, additional efforts will be allocated to southern San Rafael Swell. B) The analyses are complex and in need a statistician and modeler who can help with bioenergetic projections on the caloric costs of bighorn sheep flight, and who can help structure analytical framing responses to differing levels of recreational disturbances.

(2) *Why the work was not completed during the initial award period*. The emergence of the Covid pandemic during early phases of the award restricted some access on public lands, and hence reduced capacity to gather improved sample sizes that included more instances of recreation. Moreover, as pointed out above, sample sizes were limited and the only way to improve scientific rigor is enlarging survey areas to gather additional data on bighorn sheep from areas not over-sampled.

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Appendix 1 – 2024 Publication

Berger, J. and Cassidy, K.A., 2024. Play is a privilege in both humans and animals: how our recreation influences wildlife. The Journal of Wildlife Management, 88(8), p.e22664.

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THE WILDLIFE SOCIETY

INVITED ARTICLE

Play is a privilege in both humans and animals: how our recreation influences wildlife

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Abstract

Nature-based tourism nets roughly 8 billion annual travelers globally to all regions of Earth, with many visiting around 200,000 formally protected areas. Financially well-off tourists pay for playful activities and effects on wildlife are potentially large and relatively uncertain. Our commentary makes 3 points. First, variation in resource privileges and associated benefits characterizes not only humans but other species. Among animals, well-nurtured populations engage in more playful and leisurely activities than do those nutritionally impoverished. Privilege depends partially on birth sites, parents, and local conditions, but for humans recreation expands with monetary advantage. Second, nature-based tourism has 2 generalizable effects on wildlife, each involving degree of habituation. Among non-habituated populations, local site abandonment is frequent and modulated by seasonality, individuals' physiological states, and whether recreation is motorized or not. For habituated populations, tolerance emerges to increasing recreational exposure with some populations of species learning to rely on humans to shield as a buffer against possible predation. Third, desert bighorn sheep (*Ovis canadensis nelsoni*) offer a robust example of the issues surrounding the effects of tourism on wildlife because of the geographically complicated relationship between recreational pursuit and wildlife on public lands of the western United States. While protected for decades, females have failed to habituate to different forms of recreation at certain sites. The result has been flight or site abandonment. Biodiversity protection at numerous scales has made strong gains but is still needed where progress is stymied by income disparities, privilege, and increasing recreation ventures.

KEYWORDS
bighorn sheep, biodiversity, disturbance, human disturbance, *Ovis canadensis*

WE PAY TO PLAY – TOURISM, DOLLARS, AND BIODIVERSITY

"Where do you go to play?" It's a question I (JB) asked of friends from 2 high schools, 1 from inner-city Los Angeles (LA), the other from California's San Fernando Valley. "We go to the gym" and "we race dirt bikes out in the Mohave [Desert]" were, to the best of my recollections from my own high school days, respective answers of the 2 males. I (KC) recalled the answer from a female high school friend when I too was in secondary school in the rural Midwest: "the large backyard or the farm fields and tree lines nearby."

Now, decades later, differences in birth sites and culturally based ideology continue to affect where and how people recreate. Divisions are strong among rural and urban contexts, racial and income groups, and others (Child et al. 2015). Kids from inner LA have never seen the ocean (Kim 2014). People of color are 3 times more likely to live in nature-deprived areas than white people (Rowland-Shea et al. 2020) and, expectedly, are less likely to be involved with wildlife (Schell et al. 2020*a*, *b*) despite desires to better the environment (Cooper et al. 2015). People travel by car, ship, boat, and aircraft long distances to view wild species and enjoy nature where effects on the species and the environment can be large. Intersections between society and culture are perhaps nowhere starker than at the nexus of biodiversity and privileged economies, topics that conflate to produce the uncertainty of where we, as wildlife conservationists, are going.

More than 200,000 formal protected areas worldwide provide safeguards for biodiversity, ecological services, and human well-being (International Union for Conservation of Nature 2016, Naidoo et al. 2019). Yet many also serve as models of contemporary challenge because they function as playgrounds for visitors. Globally, nature-based travel has increased in recent years (United Nations World Tourism Organization 2023) with wealthy tourists being attracted by rare species or popular and well-visited spots. For example, revenues from the tourism industry in southern Africa exceed the combined sum of fisheries, farming, and forestry (Balmford et al. 2009). Across continents, diverse taxa spawn human curiosity and a subsequent desire to visit protected areas and untrammeled remote sites such as Patagonia, the Arctic, the Himalayas, and Southeast Asia (Jones et al. 2021, Rizzolo 2023).

Of truly iconic species, there are plenty. They include mountain gorillas (*Gorilla beringei*), elephants (Elephantidae), tigers (*Panthera tigris*), polar bears (*Ursus maritimus*), sandhill cranes (*Grus canadensis*), and gray whales (*Eschrichtius robustus*). Among off-the-radar species that tourists pay for a chance to view are hammerhead sharks (*Sphyrna mokarran*) in the Bahamas, Lake Titicaca water frogs (*Telmatobius culeus*) in Peru, Indonesian migrating shrimp (*Macrobrachium dienbienphuense*; Hongjamrassilp and Blumstein 2022), kakapos (*Strigops habroptilus*) in New Zealand, wrinkle-lipped free-tailed bats (*Chaerephon plicatus*) in southern and eastern Asia, and even the most endangered large mammal of the Western Hemisphere, huemul (*Hippocamelus bisulcus*). Unusual vagrant (outside their normal home range) birds contribute hundreds of thousands of dollars to local economies. Travelers to view a single black-backed oriole (*Icterus abeillei*) that showed up in Pennsylvania, USA, generated an estimated $3,000 ($US) a day over 67 days and other rarities result in pulses of enhanced tourist dollars on all continents for the opportunities for a sighting (Callaghan et al. 2018, 2019). Lots of money is spent to see these and other wildlife.

In the United States alone, profligate tourism is a serious issue (Colwell et al. 2012). Visitation to national parks exceeds the combined attendance of all professional football, basketball, and baseball games (Berger et al. 2014) and generates well-appreciated financial infusions to and beyond gateway communities (Wittemyer et al. 2008, Naidoo et al. 2015, Li et al. 2024). Park managers, sustainability experts, local businesses, and tourists themselves recognize the positive economic influences of nature-based tourism (Donohoe and Needham 2006) and the oft-associated negative effects such as immediate displacement of wildlife and avoidance of flocking sightseers (Larson et al. 2016*a*, 2019). Human infrastructures are used by some animals, like cheetahs (*Acinonyx jubatus*) sitting atop jeeps to hunt gazelles (*Eudorcas thomsonii*; Caro 2005), and tourists and animals can quickly become overwhelmed when swarmed by onlookers in vehicles (Burns et al. 2010, Cramer and Christ 2023). In places like Yellowstone National Park and countless other sites, ecological and behavioral responses are altered by visitors; cohorts of prey at times gather in habitats with tourists where predators may be afraid to frequent, which represents the human shield hypothesis (Berger 2007, Granados et al. 2023, Prugh et al. 2023). From a wildlife perspective, it is incumbent to know if disturbance thresholds in response to recreation exist so that policies can be devised to minimize ecological impacts (Dertien et al. 2021).

Herein, we address where and how our playful recreation affects species at the wildlife-biodiversity interface (WBI; Berger et al. 2024). Under this broader umbrella, we address 3 relationships. First, traits shared between human and non-human mammals that explain the broad category designated as play. In doing so we focus on the extent to which resource wealth affects leisure time, the propensity to play, and the type of play. Second, we concentrate on generalizable effects of nature-based tourism at the WBI. Just as insights about drivers of play are derived by understanding non-human animals, our improved knowledge about wildlife responses to human disturbance has progressed through models applying fear responses of prey-type species to predators, but research has increasingly substituted humans as symbols of possible danger (Frid and Dill 2002). Third, with western public lands in the United States serving as a microcosm of the complexity involving wildlife conservation, tourism, and economics that confront agencies and non-government organizations, we use desert bighorn sheep (*Ovis canadensis nelson*) as an example of the issues surrounding effects of tourism on wildlife.

What follows therefore is a focus on play and recreation with respect to non-consumptive uses at the WBI. We excluded hunting primarily because of the well-known direct and indirect effects of harvest on the wariness, flight, and redistribution of individuals in targeted populations (Reimers et al. 2009, Brown et al. 2020).

PLAY, RESOURCE CUSHIONS, AND PRIVILEGE

Words like play, fun, recreation, leisure, physical activity, and exercise overlap in some properties and carry attributes (Bekoff and Byers 1998) relevant to understanding how we address questions about resource and human influences on animal responses (Table 1). For instance, play in animals and play in humans are frequently viewed as motor activities lacking in immediate or purposeful goals other than fun. Notably, they might subsequently lead to some skills, but exceptions and variations of this theme are notable (Table 1).

Why play?

Play occurs in organisms from spiders and fish to birds and mammals. Functional benefits vary and may be elusive (Fagen 1981, Bekoff and Byers 1998), but a consensus is that animals play because natural selection has favored it as a form to develop motor coordination and muscle strengthening, social and communication skills, positive hormone-reinforcing behavior, and predator avoidance. Playfulness can also just be fun; among humans benefits are developmental and emotional (Brown et al. 1998, Ginsberg et al. 2007).

Forms of play differ of course, and their settings depend on evolutionary history. Cats play differently than dogs as do elephants and other species. Young individuals play more than adults but—importantly both for animals

TABLE 1 Operational definitions of some key terms used in the main body of this paper.

Concept	Description	Comment and references
Play	Animals: social or asocial motor activities lacking a purposeful goal but enabling development of physical, coordinated, or social skills; can also be repetitive, seemingly non-functional actions differentiated from adaptive structurally developed recognizable behaviors associated with Darwinian fitness. Humans: as above but can be competitive like in sports, exploratory, or otherwise used to evade reality or avoid tension	As used herein play is engagement in pursuits that may or may not be for fun as opposed to pursuits for serious practical purposes (Fagen 1981, Bekoff and Byers 1998, Burghardt 2015)
Habituation	Reduced responsiveness over time to a stimulus through exposure	Other definitions are more nuanced (Bejder et al. 2009, Blumstein 2016, Lambert and Berger 2023)
Recreation	Activities that burn calories including dancing, music, sports, and other games, travel, sightseeing, and arts and crafts	As used here recreation is fun and includes amusement or enjoyment in outdoor settings
Leisure	Departure from usual work-related schedules	Can include play or recreation as defined above (Coleman and Kohn 2022)
Physical activity	External movement that results in energy expenditures	Examples include running, driving a 4-wheel drive, biking, climbing, walking for fun (Lieberman 2020)
Exercise	Physical activity (above) with the goal of improving health	Requisite is enhanced health (Lieberman 2020)
Overlanding	Off-highway vehicle-based adventure travel	This gained popularity in Africa and spread to other continents; variations of this purist theme might include recreation with all-terrain vehicles and utility task vehicles (Overland Journal 2024)
Fun	Amusement or enjoyment	

and humans—some societies engage in more play than others. As a rejoinder for play, we know it when we see it (Fagen 1981, Bekoff and Byers 1998).

Resource cushions drive disparities in play

When it comes to play, animals and humans have much in common. For both, as an ecological antecedent, play seems to be conditional upon an adequate resource cushion. Given that play requires time and energy, it is often dependent on access to resources. If, for instance, resources are considered wealth, it follows that populations with greater accessible wealth will play more than those without it, and perhaps employ different sorts of play depending on birth sites and available playgrounds, such as noted earlier when we asked 3 high school friends where and how they play. When monetary income is used as a resource, disparities in play among human populations and ethnicity vary greatly (Jenkins et al. 2015, Rigolon et al. 2018).

In the case of non-human mammals, the biophysical environment including food quality and quantity can be a useful metric of nutritional enhancement to test the hypothesis that resource wealth modulates the extent of play among populations, which, as just noted for humans, correlates with expendable income as a resource. We use evidence from 2 types of studies—comparative and experimental—for non-human mammals that supports the idea that resource cushions affect both frequency and types of play (Sommer and Mendoza-Granados 1995, Krachun et al. 2010). And observational studies reveal how landscape structure limits mobility and shortens the timing of play (Berger 1980).

First, gray langur (*Semnopithecus entellus*; Figure 1) populations occupying habitats of poor-quality food relative to those with greater access to higher protein items revealed marked reductions in play. Individuals in the former displayed less leisure time with more energy allocated to foraging (Sommer and Mendoza-Granados 1995). Second, experiments that reduced access to maternal milk in domestic bovid calves and captive white-tailed deer (*Odocoileus virginianus*) fawns decreased play up to 35% (Muller-Schwarze et al. 1982, Krachun et al. 2010). From a biophysical perspective, play in bighorn sheep (*Ovis canadensis*) lambs in the western Sonoran Desert abruptly terminated after impalement by cactus; in areas lacking the structural impediments of cactus, the frequency of play continued longer and at older ages (Berger 1980). Resource abundance coupled with attributes of the physical environment affected time, energy, and available opportunities to meet biological needs and pursue leisurely or mobile activities.

Assuming the importance of food resources for non-humans is therefore on par with financial capacity (e.g., wealth) for people as enabled by the local environment and culture, then might we expect those with adequate or greater resources to engage in more leisure activities than those with reduced capital? Economics, leisure allocation, and different forms of recreational activity are reasonably linked to expendable capital (Naidoo et al. 2015). People with more money afford unusual and entitled forms of fun pursuits such as boating recreation, paragliding, flying, and using drones or expensive motorized travel in outdoor settings (Farrell 2020, Smeets et al. 2020).

Where and how to play?

Tourism is tightly linked to natural capital and cultural factors (Joshi et al. 2017) and (except for local restrictions during the COVID-19 pandemic) recreation throughout the American West has grown annually (Miller et al. 2020); it increased >50% between about 2008 to 2020 (Outdoor Foundation 2021). Outdoor friendliness, a value accounting for recreation opportunities balanced by exposure to pollution (IMA Research 2022), has been ranked across the United States; the degree of public lands and opportunities for activities like biking, hiking, camping, climbing, birding, snow sports, and wildlife viewing favored states in the American West, with Utah and Oregon among the top draws (Figure 2). The degree of accessible public lands helps structure activities and availability in these western states.

Among the many forms of non-consumptive outdoor play—both motorized and non-motorized—seasonal differences are large. Warmer temperatures bring biking, off-highway vehicles, hiking, backpacking, climbing, photography, and endurance races. Waterways within the mosaic of western lands have fishing, kayaking, rafting, and boating (Rosenberger et al. 2017). In winter there is skiing, snowshoeing, and snowmobiling. Obviously, other pursuits exist (Baas et al. 2020) including those where affluence enables proliferation of electric bikes, drones, overflights, paragliding, glamping, overlanding by bulked-up vehicles, and enhanced access for backcountry tele-skiing.

Climate change is affecting what, when, and where outdoor recreational activities occur such as hiking, biking, and snow-based fun (Miller et al. 2022, Wilkins and Horne 2024). Irrespective of climate, species at the WBI are also experiencing important change. The sorts of exposures to humans described above have not occurred throughout an animal's evolutionary history, and the consequent interactions experienced today differ greatly from those in their deeper past with new challenges created (Barber et al. 2010, 2011; Rebolo-Ifrán et al. 2019).

Consider helicopters in alpine zones. Species like ibex (*Capra ibex*) and mountain goats (*Oreamnos americanus*) have not adjusted to helicopter overflights despite several decades of exposure where the expectation of habituation seemed reasonable (Côté et al. 2013, Brambilla and Brivio 2018). In the Himalayas, an ungulate of similarly rugged terrain, tahr (*Hemitragus jemlahicus*), and trekkers to Everest Base Camp in Sagarmatha National Park experience controversial helicopters (Benavides 2021) every 8 minutes with attenuating exposure for 2–10 minutes on either side of low flyovers during the 2-month trekking season (J. Berger, Colorado State University, unpublished

FIGURE 1 The degree of playful interactions in societies is determined by many factors among which available resources are important, as illustrated in this bout between grey langurs at Jaigarh Fort, Rajasthan, India. Photo credit: Common License Agreement. iStock.com/abhisheklegit.

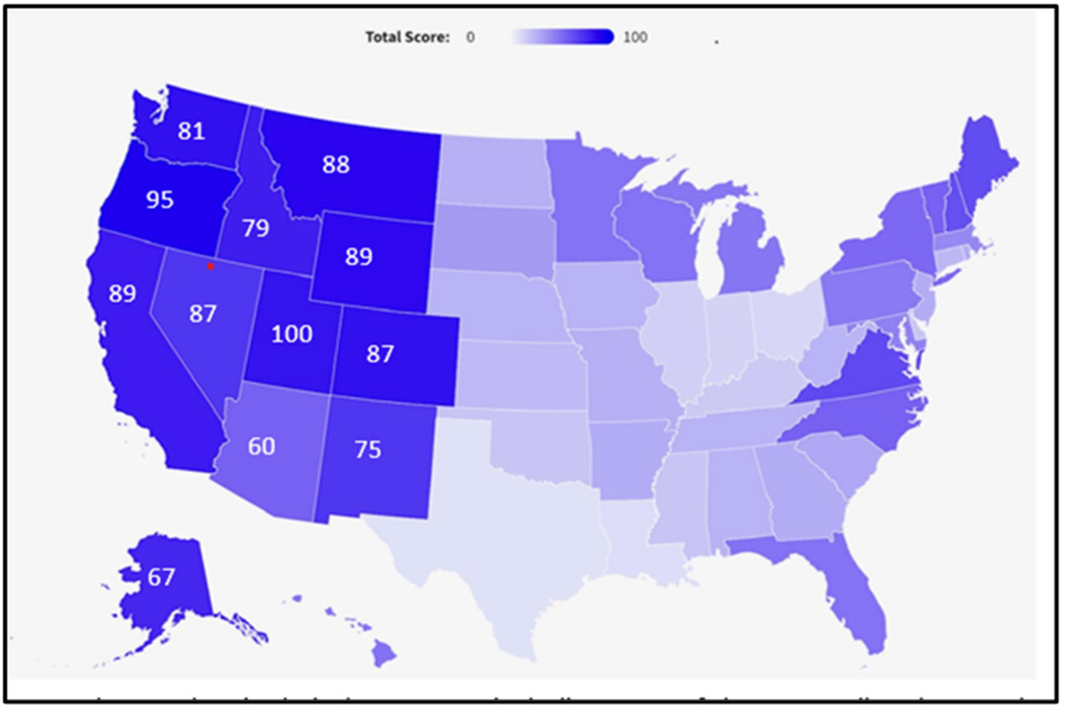

FIGURE 2 A modified map of outdoor friendliness in the United States in 2021 based on 11 metrics that included a state's institutional support for outdoor recreation, prevalence of national parks and other public lands, and chemical pollutants and air quality measures (IMA Research 2022).

data). While effects of the aerial experience remain unknown for tahr, the flights remain a massive, though controversial, economic boost to Nepal. Again, monetary privilege begets tourism. Animals intersect with recreational pursuits in this protected area and globally, with many unanswered questions about their tolerance to human disturbance (Larson et al. 2019, 2020; Lewis et al. 2021).

THRIVING ECONOMIES CAN CREATE CHALLENGES AT THE WBI

Protected areas conserve global biodiversity (Chape et al. 2005) and contribute to regional economies (Templeton et al. 2021, Zeller et al. 2024). For instance, Montana, USA, is a state ranked 43rd in population size (at slightly over 1.1 million people) but is the fourth largest in area, and approximately 5 million people visited its national parks annually and spent >$450 million, which created >6,200 jobs (Fry and Koontz 2023). It is not surprising that gateway communities are large beneficiaries of tourism. Wildlife is a primary draw in protected areas (Berger et al. 2014) with spots like Yellowstone being well-known for its habituated wildlife (Gunther et al. 2015, Cherry et al. 2018). Nevertheless, management is extraordinarily complex, affecting both visitor experience and wildlife owing to numerous interacting factors (Marzano and Dandy 2012, Marion 2016).

For visitors to and residents of gateway communities, the pleasure of seeing wildlife or making a living is weighed against additional challenges. Among these are crowded conditions, possible ecological damage (DaRugna et al. 2021), infrastructural development, affordable lodging, increased commuting time, and the maintenance of community pride (Farrell 2020). From management perspectives, there are also issues involving the nature of changing interactions with wildlife. Species and populations incur different sorts of exposure to humans depending upon locale. Well-developed and protected national parks usually have more-stringent rules about visitation and visitor behavior than non-park sites; as a result wildlife is affected by multiple types of encounters with humans across different types of land use. In protected zones with high visitation, for instance, hikers, bikers, and motorized vehicles must remain on specific pathways or trails. Conformance to these rules creates predictability and repeatable exposure, which in turn leads to some levels of tolerance. With lesser restrictions or conformity, tourism-related usage can become more erratic (Caro 2005, Knight 2009), complicating management objectives and making humans unpredictable and therefore more disruptive to wildlife.

From fright to flight

As viewed through the lens of an individual animal exposed to a perceived threat like humans engaging in recreational activities, the initial assessment is simple: Should I remain or flee?

Choices are often affected by the value of a resource such as food, the presence of offspring, or access to mates or to shelter—decisions that balance the probability of death against prolonged life and future reproduction (Ydenberg and Dill 1986, Sol et al. 2013). Behavioral outcomes, including those associated with human disturbance, have been framed within the context of predation risk (Berger et al. 1983, Frid and Dill 2002), with responses frequently assessed using indices of habitat selection or spatial arrays (Hebblewhite and Merrill 2009, Naidoo and Burton 2020, Marion et al. 2024). Reactions to enemies, or even harmless stimuli, can be passed through populations by social transmission (arguably, a form of culture), enabling these behaviors to be maintained for generations among individuals or groups (Thorpe 1963, Heyes and Galef 1996, Berger 2008, Mazur and Seher 2008). It is not mechanisms *per se* that generate patterns of species fright or flight that are of interest to wildlife managers but the consequences of human disturbances to the animals themselves (Knight and Gutzwiller 1995). Hence, when trying to minimize outdoor recreational impacts, attention focuses on the extent to which individual animals remain, flee, or simply avoid disturbance (Tablado and Jenni 2017, Dertien et al. 2021).

Behavioral plasticity intersects with response levels to nature-based tourism

Behavioral adjustments are one means by which animals modify responses to threatening and dynamic stimuli. If recreationally based disturbance has little cost to the animals, desensitization may result and ultimately habituation (Bejder et al. 2009, Blumstein 2016). Habituation, usually framed as decreased sensitivity over time to a stimulus through exposure (Table 1), is widespread among zoo animals and in numerous populations of free-ranging species. Seeking generalizability in understanding animal responses to disturbances has been a tacit goal in studies of vertebrates (Larson et al. 2019, Watson et al. 2020, Dertien et al. 2021), among which methodological approaches vary. Inferences about animal responses have been strengthened by direct and indirect observation, telemetry, motion-sensitive cameras, physical handling, simulation, and physiological measures (Marion et al. 2020).

Such methodological approaches have enabled categorizations (Dertien et al. 2021) of recreational influences on animal responses, including 1) spatial use involving avoidance of, or displacement from, areas (roads, trails), 2) behaviors paralleling those when exposed to potential predators (e.g., alarm, grouping, flight), 3) alteration of activity patterns such as vigilance–foraging tradeoffs or enhanced nocturnal activity (Gaynor et al. 2018, Lewis et al. 2021), 4) physiological responses including body condition and immune response or stress (Marion et al. 2020), 5) changes in reproductive parameters like pregnancy or fecundity, and 6) demographic trends reflecting whether populations have positive or negative growth. Within each category, assessments have been quite specific. For instance, for behavioral responses similar to those during predator exposure (category 2 above), experimental investigations show that flight initiation distances vary by type of disturbance but can be shaped by prior experience (Blumstein and Fernandez-Juricic 2010) or by applying models of bioenergetics of escape (Lawler et al. 2005, Srinivasan et al. 2018, Kay 2024); for example, trail use by humans was associated with increased use by carnivores at night (Lewis et al. 2021). Other studies based on naturalistic comparison coupled with experiments in large national parks reveal that prey species discriminate humans from carnivores and habituate to the former (Caro 2005, Berger 2008, Carthey and Blumstein 2018). Outside of parks, fear of predators and humans is conditional, and may be distinguished based upon level of exposure and intensity of reinforcement (Griffin et al. 2001, Clinchy et al. 2016), though humans and predators may both be viewed by prey as danger or just unwelcomed stimuli.

Seasonality also dictates levels of wildlife response, especially to non-motorized recreation. In winter, skiing and snowshoeing have disproportionately larger influences on animal movements and vigilance than during other seasons (Larson et al. 2016*a*), but this is not always the case (Harris et al. 2014, Shannon et al. 2017). And low levels of summer hiking cause changes in activity or avoidance among carnivores and ungulates (Sytsma et al. 2022). In more heavily visited protected zones, mountain bikes and motorcycles reduced the immediate use of areas by wildlife more so than hikers and horseback riders (Naidoo and Burton 2020). Yet when effects of sound and sight were separated through experimental presentations to 7 species representing ungulates and carnivores, loud hikers had a greater inimical effect than did off-road vehicles; species abundance was 1.5 times lower the week following recreational noise exposure and elk (*Cervus elaphus*) were especially sensitive to noise (Zeller et al. 2024). Overall, exceptions in wildlife responses to human recreation can be many (Buxton et al. 2020), rendering generalizations difficult (Marion et al. 2024).

Behavioral plasticity has enabled animals to capitalize on wildlife-based tourism to enhance access to minerals and food (e.g., bears [*Ursus* spp.] and coyotes [*Canis latrans*]), and sometimes as shelters to buffer against potential predation (Sarmento and Berger 2017, Granados et al. 2023). Pregnant moose (*Alces alces*), for instance, capitalized on roads across a decade, progressively moving closer to give birth in areas that grizzly bears (*U. arctos*) avoided because of human presence (Berger 2007). A counter effect of the human shield hypothesis is potential habituation or a reduction in wariness, by which animals that subsequently depart protected areas become more susceptible to predation (Coleman et al. 2008) or human hunting (Shannon et al. 2017).

In sum, while much is known about the immediate displacement and avoidance of specific sites, less clear are biological consequences of recreational-created disturbance such as those affecting body condition, immune systems, and fitness-related correlates. We know tolerance and habituation to people and infrastructure occur when externalities are repeatable and predictable, though exceptions exist (Larson et al. 2019). Problematically, current overt measures of habituation and tolerance in wildlife are rarely assessed at levels where potential chronic stress may be detectable (Dickens and Romero 2013).

A MICROCOSM FOR NATURE-BASED RECREATION

The attraction of public lands and their wildlife

Most (90%) of America's public lands are in the contiguous western states and Alaska between the Rocky Mountains and Pacific (Figure 2); over 45 million km^2 are under federal control and are used extensively by recreationists as nature's playgrounds (Stowell 2016, Keiter and McKinney 2019). The Colorado Plateau is a reasonable microcosm within the backdrop of these western federal lands to understand how recreational pursuits affect wildlife. At about 388,000 km^2, and similar in area to Montana or Zimbabwe, the Colorado Plateau is more than 50% public lands (Peaks, Plateaus, and Canyons Association 2023). With 27 national park units including Grand Canyon, Arches, Zion, 17 national forests, 26 wilderness areas, and millions of hectares of land managed by the Bureau of Land Management, it is a destination for many to play in nature. Southeast Utah is one such primary target with alpine peaks to 3,800 m and deeply incised canyons of geological and archeological note. The hub is Moab, a small remote desert town of 6,000 people.

Moab attracts about 4–5 million people annually, somewhat more than Yellowstone National Park; the broader southeastern Utah region receives greater numbers of visitors than Moab, but because registration is not required for lands managed by the Bureau of Land Management or the United States Forest Service, even approximated numbers are unknown. Because of differing federal and state policies, recreationists in southeastern Utah can engage in many activities without some prohibitions found in national park units. An estimated 100,000 mountain bikers come annually, in spring. Motorcyclists, all-terrain 4-wheeled vehicles, electric bikes, road bikes, and hikers use the land; kayakers and rafters are in rivers and equestrians are on trails. In the air are drones without restriction. Noise emanates from tourist-sponsored scenic aerial overflights in commercial helicopters and planes, and private charters. The monetary cost for rentals or guides for these different activities is substantial and underscores recreational privilege (Table 2). So do resorts that provide high-end glamping (i.e., glamorous camping) with nightly prices from \$500–\$7,000/night (Amangiri 2024). Many recreationists have the financial means to bring their own bicycles, motorcycles, and all-terrain vehicles, and use trailers for transport with large expensive trucks. Asymmetries in opportunity persist as most visitors are white and financially comfortable, with people of color representing ≤1% of all visitors (Cooke et al. 2018; Schell et al. 2020*a*, *b*). Tourism diminishes in winter, which reduces economic benefits to the business community (Wiedmann et al. 2020), though this lull offers the natural environment a bit of reprieve.

Wildlife and habitats in the region are highly exposed to direct and indirect effects from recreation. These involve both the physical and biotic environment. Alterations of cryptobiotic soils and soil compaction are serious consequences of hiking, biking, and motorcycles, as is the proliferation of unauthorized dirt spoor, 2-tracks, and roads by overland recreators (Monz et al. 2013). Water sources, some constructed for wildlife, attract mammals like coyotes, ring-tail cats (*Bassariscus astutus*), pronghorn (*Antilocapra americana*), badgers (*Taxidea taxus*), kit foxes (*Vulpes macrotis*), gray foxes (*Urocyon cinereoargenteus*), bighorns, and mule deer (*Odocoileus hemionus*). Water also attracts people, and those camping nearby deter wildlife usage (Marion et al. 2018). Regions around campgrounds have increased densities of ravens (*Corvus corax*) and associated predation on nesting birds (Marzluff and Neatherlin 2006). Hikers affect nesting Mexican spotted owls (*Strix occidentalis lucida*; Swarthout and Steidl 2013). While tourism brings money for business, its inadvertent effects on wildlife on the public lands within or outside national parks of southeastern Utah are not well understood (Monz 2021).

Desert bighorn sheep – from fear to escape

Bighorn sheep, like other sexually dimorphic ungulates, segregate seasonally where males and females live separately except during the mating period (Bowyer 2022). This spatial partitioning of habitats has strong implications for understanding potential influences of human recreational disturbance, particularly the relative allocation of the 2 sexes to detect perceived danger.

TABLE 2 Estimated costs of rental vehicles (or guides providing those rentals in parentheses) by select activities in the Moab, Utah, USA, area in 2024. Purchase costs are highly variable, and the range reflects low- and high-end purchases. Sources include personal experience (JB) and responses generated by artificial intelligence (Copilot, Microsoft, Redmond, WA, USA).

Type of activity	Rental cost/day ($US)	Insurance or transportation ($US)	Purchase cost ($US)
Electric bike	200–270[a]	15–50	300–6,000
Mountain bike	160–280 (300–500)[a]	15–50	400–6,000
Motorcycle	345–400 (1,100–1,200)	700/rental deposit	2,000–15,000
Utility task vehicle (or all-terrain vehicle)	470–700	4,000 holding fee	
Jeep	310–475 (320–550)	40/day	
Helicopter flight	490–600/hr		
Aerial overview	300/hr		
Sleeper van	145–325	50–100/day	75,000–200,000

[a]Reflects costs for 2 people because these items are rarely rented alone.

The duality of avoiding predation (or human disturbance) and finding appropriate nutrition challenges the sexes differently. Females are consistently more wary than males (Berger 1991, Mooring et al. 2004) and to enhance safety they use more rugged habitats than males (Bleich et al. 1990). In desert environs, both sexes experience serious seasonal stress due to summer water needs (Krausman and Etchberger 1995, Cain et al. 2008, Glass et al. 2022). Under some circumstances, both sexes increase tolerance and reduce wariness to humans, and can be found at swimming pools, on golf courses, and near traffic and humans along salted roadways (James 2016, Bighorn Institute 2024). Physiological need may override fear (Lowrey and Longshore 2017, Harris et al. 2020), and for bighorn females the demands of late stages of gestation and lactation equate to enhanced risk-taking (Berger 1991, Blum et al. 2023) and exposure to recreationists.

In southeast Utah the arrival of warming spring temperatures brings tourists. This period coincides with the last trimester of pregnancy in bighorns when exponential fetal growth imposes greater nutritional demands on expectant mothers (Robbins 1983); nitrogen needs increase by about 45% (in similar-sized domestic female sheep; Robinson and Forbes 1968). Spring is also when grasses high in nitrogen first emerge, and females in late gestation must balance their heightened needs for protein with exposure to human disturbances by choosing whether to stay or to flee (Berger 1991). If the latter, they must decide when, at what speed, and how far, choices predicated on types, severity, and prior exposure to recreational disturbance (Figure 3).

To address questions about potential disturbance and distributional patterns, telemetry data have been used to disentangle relative effects of food and minerals from tolerance to increased predation risk (Whiting et al. 2010, Dwinnell et al. 2019, Brushett et al. 2023), using resource selection approaches including locales in Utah (Sproat et al. 2019). Despite the telemetric benefits to understand spatial usage, a limitation of such approaches is a failure to appreciate the causes of erratic or long-distance movements; these might or might not be linked to recreation.

A predatory encounter, a random walk, or merely a startled response could spur flight of sheep, but assessing causation would be near impossible without some type of observational or otherwise strongly inferential data (as demonstrated in Cassidy et al. 2015, Cassidy and McIntrye 2016). While such movements may be infrequent, cases occur such as dogs chasing sheep (Figure 4) or inadvertent flight from jeeps, both of which resulted in 7-km linear movements in 30–36 hours (Figure 5) and area avoidance for several weeks. Beyond a 1-time disturbance, the role of multiple exposures to recreational disturbances in a given period has yet to be investigated. We have observed,

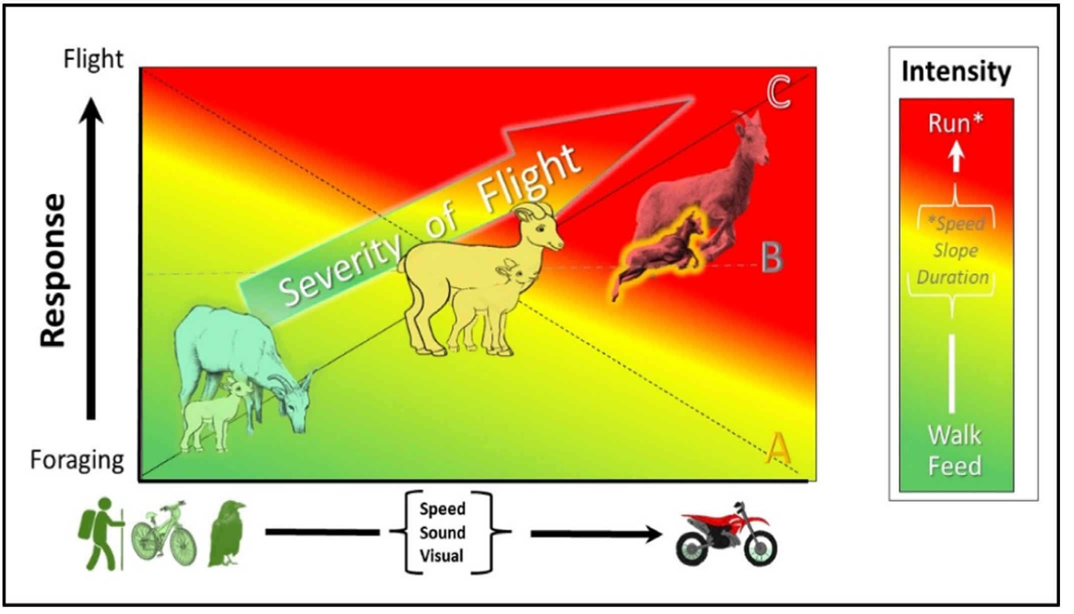

FIGURE 3 Schematic of intensified (green to red) energetically costly responses of desert bighorn sheep to stimuli in Utah, USA, with feeding being a net energy gain and flight across steep terrain at high speeds being the costliest. We present the types of possible disturbance illustrated on the *x*-axis; A–C reflect hypothesized differential responses. We include the raven as a neutral stimulus. Intensity can be measured by relative expenditures of joules (Denryter et al. 2021) and refined by knowledge of durational use of slope and speed of travel.

however, multiple exposures of female bighorns to hikers within a 30-minute period that resulted in an immediate and prolonged group flight of 5 km. Long post-disturbance flights also derived from motorcycling recreationists, with running displacements >3 km in 13 minutes.

The detection of such patterns through direct observations requires persistence and luck, and thus is a questionable efficient use of time. When coupled with other field approaches such as experimental playbacks of sound or visual cues (Stankowich 2008), chance anecdotes build into data sets (Berger 1991, Berger et al. 2001). Moreover, it is not our intent here to single out possible extreme responses as a rule but to highlight that a species (e.g., bighorn sheep) with morphological constraints associated with running long distances that is not known to be fleet like an antelope (Geist 1971), just does not simply disappear over a hill and continue feeding, as might otherwise be assumed. While none of the above cases were intentionally caused by outdoor enthusiasts, females in late gestation incur energetically significant costs when displaced long distances from choice feeding sites.

Sometimes non-harassed individuals may tolerate proximity to hiking, biking, and vehicles in Canyonlands National Park in southeastern Utah (Papouchis et al. 2001). Two decades later, we detected a 14-fold increase in motorized vehicle use on adjacent Bureau of Land Management properties where less restrictions exist because such recreation is not under regulation (J. Berger, unpublished data). Elsewhere in the world and outside of protected areas, fear of humans is noticeable among many species (Caro 2005, Kays et al. 2017), including those with and without poaching (Connor et al. 2001, Foley et al. 2001). It is not obvious why some female bighorn sheep, at least in numerous regions of southeastern Utah, still appear frightful of humans rather than being on a strong path toward habituation.

Possible explanations for the reduced adjustments to human disturbance by bighorn females include legacy of past harvest, seasonal sensitivities associated with prenatal nutrition (e.g., supporting fetal growth), and insufficient

FIGURE 4 Images of flight in a female group of desert bighorn sheep on Bureau of Land Management (BLM) lands about 5 km east of Canyonlands National Park, Utah, USA, in spring 2023 (left), and a dog noted by the arrow in pursuit of a group of 12 desert bighorn sheep (6 in photo) on BLM lands in the San Rafael Swell, Utah, in spring 2023 (right). Photo credit: J. Berger.

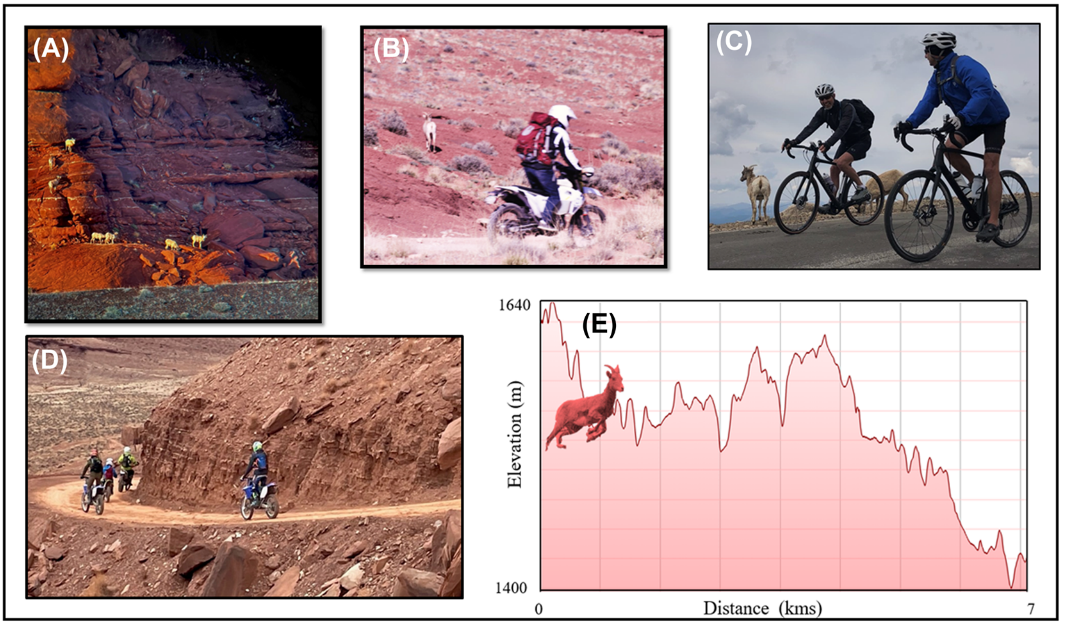

FIGURE 5 Mosaic of desert bighorn sheep responses to recreation in southeast Utah, USA, 2022–2023, including A) typical habitat use by females, B) flight from a motorcycle, C) a low-level response to bicycles, D) a motorcycle cluster, and E) flight path elevation (*y*-axis increments at 24 m) and post-disturbance distance (*x*-axis increments at 0.85 km) from 2 jeeps. Maximum elevational shift on slopes was 67%. Photo credits: J. Berger.

exposure to vehicles. Hunting, however, appears least tenable as a cause for timidness because females experience no harvest. Perhaps exposure to humans is equivalent to mammalian predators. If so, then responses should be similar, a proposition that has not been tested. It is also possible that the responses of gestating bighorns to recreational disturbance change seasonally. In the spring and with greater needs to fuel growth of late trimester fetuses, perhaps females are more (or could be less) sensitive to other human intrusions than during other periods when reproductive investments such as pregnancy or lactation are relaxed. Neither is it known if vehicular and non-motorized traffic is insufficiently regular, at too low a threshold, or varies in unpredictable spatial routes to warrant habituation. It could be that cumulative effects of disturbance, such as >1 encounter on the same day, become overwhelming. Still, many sites exist where female bighorns habituate to people and vehicles. Again, relationships among habituation, chronic stress, and long-term fitness are often unknown.

The potential to recreate on public lands in the western United States, including the Colorado Plateau, attracted about 290 million visitors in 2017 (Schimel and Warren 2018), a number that post-COVID-19 pandemic might be considerably higher. This sort of tourism has strengthened rural economies, but it also affects natural and cultural landscapes and organisms at the WBI. Analyses of the possible influences of motorized and non-motorized activities have largely been spatially based using resource selection models focused on how arrays of roads and trails affect either ecological communities or individual species (Larson et al. 2016*a*, 2019; Naidoo and Burton 2020). Other studies concentrated on effects of anthropogenic noise (Barber et al. 2010), used field experiments to broadcast sounds (Zeller et al. 2024), or employed observational approaches to measure wariness and flight initiation distances (Blumstein and Fernandez-Juricic 2010). Despite the inevitability of human disruption to bighorn sheep, other species, and ecological processes, much remains to be learned. Inter-population variability in habituation may or may not be large and has yet to be systematically evaluated by parsing out the role of different factors. Moreover, little is known about the attributes of chronic stress of disturbance or the timing by which changes in recreational management policies may benefit the demographic responses of target species.

PRIVILEGE, PLAY, AND PROGRESS TO PROTECT WILDLIFE

We began this essay with retrospective answers from 3 long-ago high school friends about their respective playgrounds. Socioeconomic and geographical circumstances established site-specific activities. A gym for basketball was preferred in LA and woody thickets in Iowa. Only with financial backing was one able to purchase and ride motorcycles across deserts. Birth sites, culture, and income disparities intersect to shape where and how we, as humans, recreate. People with greater fiscal security enjoy additional leisure time and opportunities to engage in outdoor activities (Jennings 2007, Jennings et al. 2016). With monetary privilege as a cushion, vacationers play in wild places with wildlife (Benoit 2019, Farrell 2020).

Throughout, we relied on ecological frameworks to examine consequences of nature-based recreation on wildlife using a predation risk paradigm (Frid and Dill 2002). We connected types of recreation with enjoyable pursuits on public lands (Table 2), for which monetary advantages enable leisure time and outdoor fun. Rather than understanding consequences *per se*, it is also valuable to examine causal pathways leading to pursuits of outdoor recreation. Resource cushions are a common denominator in the play of people and animals. As an ecological surrogate for money, nutritional security in animals can be viewed equivalently because it partially guides the availability of expendable energies for fun, play, and other activities. Food sufficiency is one such factor (Barber 1991), as it can double a propensity to play in wild mammals (Sharpe et al. 2002). Without appreciating causal pathways associated with play or privilege, whether for people or animals, our ability to predict how, when, and where nature-based activities unfold will be limited.

As noted, among both animal and human societies, birth sites and adjacent physical settings establish or limit opportunities for play. For instance, because of the low productivity of their arid environment, group sizes of desert bighorns are smaller than in more mesic locales; lambs from the former biomes have few playmates upon which to practice skills, and they contend with painful cacti, which further limits or truncates interactions (Berger 1980) or, in unusual circumstances, results in death (Jansen et al. 2005). Site-specific locality and privilege also place obvious limits on opportunities for other sorts of outdoor recreation.

Living adjacent to open space or public lands does not guarantee access to them. For example, roughly 70% of inner-city kids in Denver, Colorado, USA, have not been to the nearby Rocky Mountains; the nature gap is deep—people of color are less likely to have generational wealth, and have less access to social, economic, and physical health benefits of outdoor recreation (Larson et al. 2016*b*, Rowland-Shea et al. 2020). Not only does circumstance dictate opportunity for people, but through happenstance such as birth locality, some wildlife will be exposed to more recreational activity. Yet the potential for behavioral adjustments by individual animals will govern the magnitude of recreational effects on their responses.

Given sensational growth in global visitation to wild places, including recreation on America's public lands, conservation challenges fall into 2 primary realms: for animals, the ability to sustain disturbances without inimical consequences; for humans, a willingness to accept mitigation such that negative effects at the WBI can be dampened. Burgeoning recreation brings activities and exposes wildlife to unfamiliar items such as drones, paragliders, hot air balloons, and increasingly specialized forms of electric and non-motored vehicles that only 2 decades ago were uncommon or non-existent. Novelty can engender strong anti-predatory responses, which can be mitigated with some level of tolerance or habituation; however, animal sufferance should not be the sole solution to human disruption of wildlife.

Management authorities are indeed sensitive to wildlife harassment, but nature-based tourism and recreational enjoyment constitute a statutory component of multi-use public land missions. This, in turn, creates serious challenges because economic and conservation interests are, understandably, imperfectly aligned. Nonetheless, effective, though sometimes controversial, regulations of recreational activities have been deployed for species or at specific sites. Notable ones include policy recommendations for whale watching (Higham et al. 2014), limiting number of tourists or timed entry systems for access to some public lands (National Park Service 2024), and adhering to requisite safe distances from dangerous or sensitive wildlife (e.g., bison [*Bison bison*]), bears, nesting raptors). Registration and safety training or commercial licensing is either required or advised for wildlife tour group operators in American national parks and for some Bureau of Land Management areas (National Recreation and Parks Association 2024), and broad similarities exist for wildlife guiding in Kenya, Namibia, and South Africa (Safari Club International 2024, Safarifrank 2024). Seasonal closures or other restrictions on access protect spawning sites, nesting raptors, denning bears and wolves (*C. lupus*), congregating waterfowl, and other birds through limits on hiking, boating, rafting, and climbing. Dirt roads and tracks are sometimes closed seasonally or permanently, and caps can be placed on tourist numbers (Larson et al. 2016*a*), a well-established practice decades ago to protect mountain gorillas (Weber and Vedder 2002). Educational outreach concerning responsible nature-based recreation and wildlife is central among all agencies that manage wildlife or land, or are tasked with travel and tourism, but education alone has not been a panacea for success (Thomas et al. 2019).

Conservation gains for wildlife and biodiversity come about because of nameless advocates who believe that our human footprint needs to be dampened and are bolstered by research on effects of nature-based recreation. Massive economic growth and interest among nature- and wildlife-based tourists and agencies have facilitated policy implementation at regional, national, and international levels. While these conservation actions help protect species, human compliance is a continuing challenge such that mitigation must be effective without the perception of excessive top-down regulation, which does not always sit well with components of the local or broader populace (Nie 2004). In limited realms, a pervasive ideology calls for reckless off-road use on public lands (Wuerthner 2007, O'Reilly 2017); others push for non-motorized access to formally designated wilderness areas where all mechanized objects (e.g., mountain bikes) are prohibited by statutory legislation by the United States Congress (Proescholdt 2024).

Summing up, we know that playful behavior is characteristic of many species and those with access to improved resource cushions engage in more playful activities. For humans, this easily amounts to more nature-based recreation. An undoubtable future challenge will be to enjoy the natural world and wildlife while easing negative effects at the WBI.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ETHICS STATEMENT

No animals were involved in the preparation and execution of this manuscript, although a component of this paper was based on observations of desert bighorn sheep for which a flight response of sheep occasionally occurred.

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