DOCKETED	
Docket Number:	24-OPT-03
Project Title:	Soda Mountain Solar
TN #:	261255
Document Title:	Christina Aiello Comments - Impacts to desert bighorn sheep
Description:	N/A
Filer:	System
Organization:	Christina Aiello
Submitter Role:	Public
Submission Date:	1/23/2025 10:54:32 AM
Docketed Date:	1/23/2025

Comment Received From: Christina Aiello
Submitted On: 1/23/2025
Docket Number: 24-OPT-03

Impacts to desert bighorn sheep

Additional submitted attachment is included below.

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1/23/2025

Re: Soda Mountain Solar Docket #: 24-OPT-03 Potential Impacts to Biological Resources

To representatives of the California Energy Commission:

We are writing to express concerns about the planned Soda Mountain Solar Project. As demonstrated by research we and our colleagues have conducted since the early 2000s, connectivity among bighorn sheep populations is a critically important process in California's desert bighorn populations, which represent one of the largest intact native metapopulations of bighorn sheep in the United States. Our research has demonstrated the importance of restoring the connection across I-15 between the South Soda Mountains and the North Soda Mountains, as a regionally-important link for gene flow and colonization. Notably, California wildlife and transportation agencies and a private high speed rail company have agreed to construct a wildlife overpasses that would reconnect desert bighorn habitat across I-15 near the Soda Mountain Solar project site. The overpass is expected to benefit desert bighorn resilience in the region and contribute to the stability of bighorn-focused recreation associated with the Mojave National Preserve, including local hunting opportunities. The efforts to restore connectivity over the highway are therefore both ecologically important and widely supported by diverse stakeholders in the region.

The risks posed by a development at this location are disproportionately large given the initiatives underway to reconnect habitat across one of California's highest priority barriers to wildlife movement. We have attached a report for you to consider that describes the research and data that support this statement. This letter and report reflects our professional experience and thorough knowledge of desert bighorn sheep ecology at the project site and surrounding region, but does not reflect an official position of Oregon State University, our current employer.

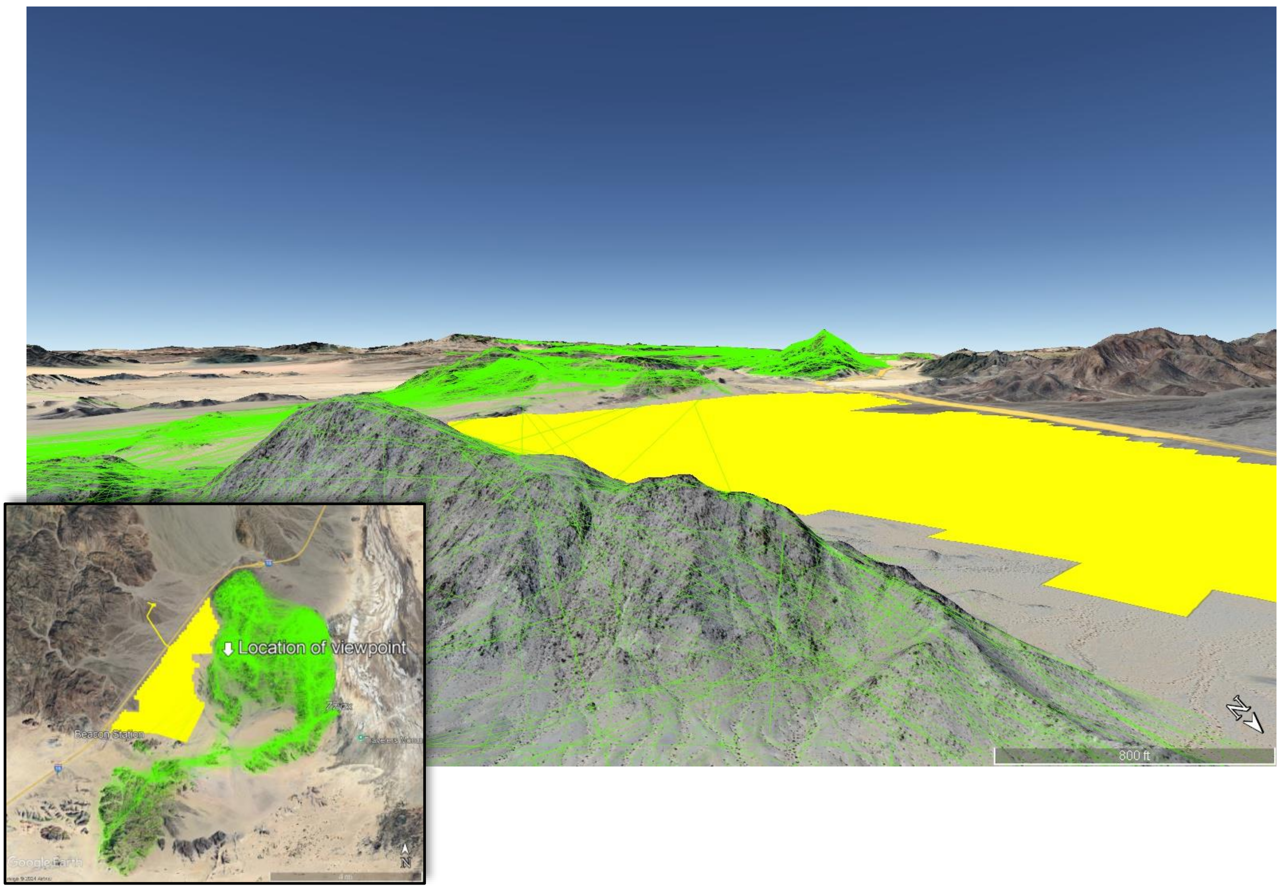
Sincerely,

Christina Aiello, Ph.D.
Research Associate, Department of Fisheries, Wildlife, and Conservation Sciences
Oregon State University

Clinton W. Epps, Ph.D.
Professor, Department of Fisheries, Wildlife, and Conservation Sciences
Oregon State University

Potential impacts of the proposed Soda Mountain Solar development on desert bighorn sheep

A report prepared for the National Park Service and California Department of Fish and Wildlife



Hypothetical ground-level view of the Soda Mountain Solar proposed footprint (yellow) from a location regularly used by bighorn sheep in the adjacent Soda Mountains. The view is facing southwest toward a key movement corridor that connects bighorn populations in the Soda and Cady Mountains. The green lines show movement trajectories for 2018-2021 of 8 bighorn collared in this region and analyzed in Aiello et al. (2023) – the results of which are discussed in this report.

[*]Christina M. Aiello[1], Clinton W. Epps[1]

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*This report was reviewed and supported by Region 6 desert bighorn biologists Danielle Glass and Rick Ianniello

Abstract

The National Park Service manages lands that contain vital desert bighorn sheep habitat in California, including Death Valley National Park, Mojave National Preserve, and Joshua Tree National Park. While these habitats provide refuge for persistent and genetically diverse bighorn populations, their health and resiliency is dependent on connections with surrounding populations on non-NPS lands. A proposed solar development adjacent to Mojave National Preserve would overlap with known bighorn sheep activity, occur within visual proximity of critical movement corridors of desert bighorn in the region, and abut a costly and well-supported initiative to restore a bighorn movement corridor with a wildlife overpass across I-15. The existing and future movement corridors provide extensive benefits to bighorn locally and regionally and promote resiliency in times of environmental stress. This assessment discusses the science that indicates **the risks posed by a development at this location are disproportionately large given the bighorn conservation initiatives underway in the region**. We also discuss the mitigation recommendations posed in a "Desert Bighorn Sheep Study" prepared for the California Department of Fish and Wildlife by Dudek, which was submitted as Appendix D2 with the Soda Mountain Solar project application to the California Energy Commission. While the Dudek report recommended a 0.25 mi project buffer between the footprint and 10% sloped habitat, **the available data indicate a larger buffer (0.62 – 1.24 mi) between the facility and bighorn habitat would be appropriate to reduce negative impacts, coupled with delayed construction until after movement has re-established across the highway**. These modifications would better protect irregularly used habitat and reduce the risk of behavioral avoidance of habitat near the project site that has been observed in other ungulate species near similar developments. Increasing the distance between the project and preferred bighorn habitat would also better account for the structure's likely visibility to bighorn, which may influence their movement decisions. We consider these measures warranted considering the large and long-term ecological benefits at stake at this site.

Contents

Overview

Desert bighorn sheep (*Ovis canadensis nelsoni*) occur in small populations throughout mountain ranges in Southern California and persist as a metapopulation – a connected network of populations. The bighorn metapopulation is more resilient and adaptable as a whole than populations in isolation (Schwartz et al. 1986, Bleich et al. 1990, Epps et al. 2006, Hogg et al. 2006, Dugovich et al. 2023). However, numerous mountain ranges and previously connected populations have been fragmented by human-made barriers; the Soda Mountains, for example, is currently split by interstate highway 15 (I-15). The northern Soda Mountains, which provided seasonal habitat and a movement corridor that allowed gene flow between populations, cannot be readily accessed by the bighorn population now restricted to the southern Soda Mountains (Epps et al. 2005, 2013, Creech et al. 2014, Aiello et al. 2023). The fragmentation of habitat by I-15 has substantially impacted genetic connectivity not only of adjacent populations, but of the larger surrounding bighorn metapopulation (Epps et al. 2005, Creech et al. 2014).

State agencies have invested heavily in an ongoing project to construct wildlife overpasses across I-15 – an estimated $120 million investment (California Department of Fish and Wildlife 2023). These structures are expected to restore habitat connectivity for bighorn and other species, with completion estimated in 2028. The project benefits to bighorn sheep, however, are conditional on present bighorn distributions and movements continuing without further disturbance. A proposed solar installation adjacent to the Soda Mountains, to one of the future wildlife overpasses, and to existing bighorn movement corridors (Figure 1), could threaten the effectiveness of the overpass project as well as the existing connectivity and habitat use of nearby desert bighorn populations.

This assessment addresses the unique situation of the Soda Mountain area bighorn and the surrounding metapopulations to evaluate the potential impact of the Soda Mountain Solar project. We summarize the available science on bighorn and related wildlife ecology and describe the risks posed to the species by this development. We consider risks not only to the current behavior and distribution of local bighorn, but also risks posed to the expected benefits of connectivity restoration to desert bighorn metapopulations in this region. Two prior assessments (Epps et al. 2013, Dudek 2024) of this project's potential impacts echo the concerns presented here, but we offer additional details from a recent movement analysis of bighorn from the Soda Mountains (Aiello et al. 2023) and a viewshed analysis of the project area relative to areas of regular bighorn activity. We conclude with a summary of the potential risks and recommended actions to protect vital bighorn movement corridors in the region.

Project area

The Soda Mountains are located in the Mojave Desert region of southern California in San Bernardino County, near Baker, CA. The range borders the northwestern boundary of the Mojave National Preserve, with the southeast corner of the Soda Mountains included in the Mojave Preserve and accessed via Zzyzx Road. Since its construction and opening in the 1960s, I-15 has divided the range into two distinct areas (heretofore referred to as the North and South Soda Mountains). Much of the North Soda Mountains was designated as wilderness in 2019.

The Soda Mountain Solar facility is proposed on BLM land west of Mojave National Preserve and adjacent to I-15. The project footprint lies between the North and South Soda Mountains, on the south side of I-15 (Figure 1), and would include areas with desert washes, open scrub and alluvial fans. The project would also border a BLM-designated open OHV area accessed via Rasor Road (Figure 2).

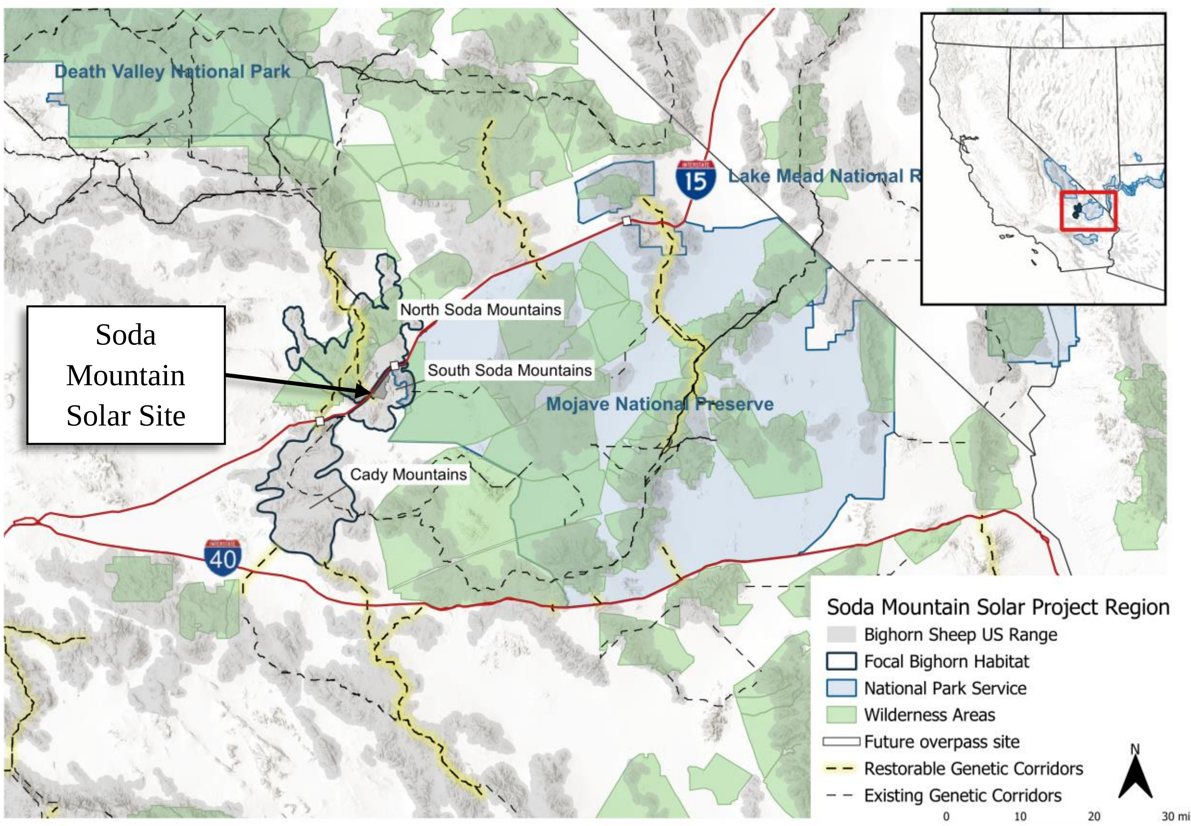

Figure 1. Focal area of the proposed Soda Mountain Solar development relative to two adjacent mountain ranges occupied by desert bighorn sheep (the Soda and Cady Mountains) and surrounding bighorn sheep habitat. Desert bighorn populations are linked by inter-mountain movements and function as a metapopulation; some of these expected links have been mapped using genetic analyses that indicate movement corridors have been fragmented by major highways (Epps et al. 2005, 2007; Creech et al. 2014). The Soda Mountain Solar facility would be adjacent to existing and restorable movement corridors that play significant roles in region-wide connectivity of desert bighorn populations. Plans to restore these corridors include building three overpasses along I-15, with construction scheduled for 2025 - 2028.

Desert bighorn sheep distribution and management

Bighorn sheep distributions throughout the west experienced an extreme contraction after Euro-American settlers colonized bighorn-occupied states (Buechner 1960). The combined stressors of human habitat disturbance, introduction of non-native livestock and pathogens, and climate likely interacted to eliminate bighorn from many areas with suitable habitat (Buechner 1960, Whiting et al. 2023). Bighorn recovery following these contractions has been the product of livestock removal, re-introduction efforts, and natural recolonization of vacant habitat (Whiting et al. 2023). Wehausen et al. (1987) estimated that bighorn were likely extirpated from the Soda Mountains by 1850. Though nearby bighorn populations in ranges like the Cady Mountains persisted, many continued pressures limited the growth of bighorn populations and expansion into their former habitat until late into the 20th century. In 1969 surveys, Weaver noted evidence of transient use of the Soda Mountains, but classified it as marginal habitat (Weaver and Mensch 1970). The state continued to consider the Soda Mountains as vacant habitat until the early 2000s, when the first individuals were documented by staff at the California Desert Studies Center at Zzyzx, CA (Abella et al. 2011). The first population census in 2012 estimated a population of 51-100 individuals had established in the southern end of the Soda Mountains, with later genetic data indicating the colonizing bighorn likely came from the Cady Mountains (Epps et al. 2018). The Soda Mountain population persists to this day at similar numbers (Vu et al. 2021).

Bighorn habitat in California is distributed in such a way that historically, desert bighorn populations were likely extensively connected throughout their range (Epps et al. 2007, Creech et al. 2014). The Soda Mountains, along with over 70 other desert ranges throughout California provide habitat for distinct populations of bighorn sheep that interact to form metapopulations – collections of connected populations (Bleich et al. 1990, California Department of Fish and Wildlife 2024). California uniquely has the largest collection of native bighorn populations in the U.S., as opposed to other states that have reintroduced many populations via translocations from distant source populations (Western Association of Fish and Wildlife Agencies Wild Sheep Working Group 2015, Whiting et al. 2023). This means that California's desert bighorn populations are of prime conservation and scientific value, as their natural history is less altered by recent human intervention relative to other regions and populations.

In addition to their ecological importance, bighorn sheep are valued for their cultural significance and recreation opportunities (wildlife viewing, permitted hunting) by a diverse community in the desert region. Tribal nations that live throughout the desert valley and mountain regions of southern California have long-standing traditions and connections to bighorn sheep, with some tribes expressing their support for restoration of bighorn populations and habitat (CDFW 2024). The Soda Mountain population regularly uses water sources and adjacent rocky habitat along Zzyzx Road within the Mojave National Preserve, providing some of the easiest-to-access locations for bighorn viewing opportunities in the Preserve (D. Hughson, NPS personal communication). The adjacent habitat to the east in the Mojave Preserve, along with BLM lands to the west in the Cady Mountains, are designated by the California Department of Fish and Wildlife (CDFW) as desert bighorn hunt zones (Figure 2). Hunting opportunities are reserved for populations large and stable enough to support limited loss of individuals (CDFW 2024). Though the Soda Mountains are not currently a huntable area, the benefits provided from accessible habitat in the Soda Mountains and from connectivity between bighorn populations play a role in maintaining stable populations within the area and sustaining future hunting opportunities.

Developments in the region such as highways like I-15 and I-40, have fragmented habitat, disrupted bighorn movements and reduced connectivity and gene flow between some populations, which can affect genetic diversity of populations within the larger region (Epps et al. 2005, Creech et al. 2014, Aiello et al. 2023). The CDFW considers the preservation and restoration of natural connectivity between populations a key management goal and integral to the species' health and survival (California Department of Fish and Wildlife 2024). Currently, three wildlife overpasses are planned along I-15 as part of this strategy, with one of these structures sited within 1.5 miles of the project footprint (Figure 2).

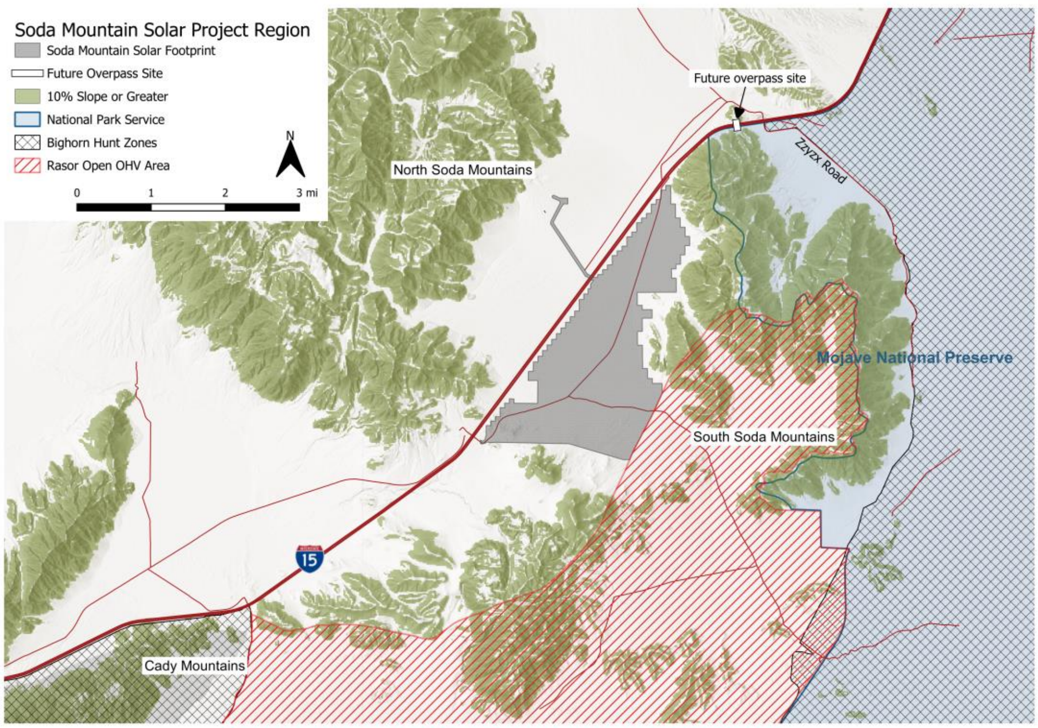

Figure 2. Zoomed in map of the proposed Soda Mountain Solar footprint relative to the North and South Soda Mountains (which is fragmented by interstate highway 15), the Cady Mountains, a BLM-designated open OHV area, CDFW-designated bighorn hunt zones, and the Mojave National Preserve. An overpass intended to promote bighorn movement across the highway will be built at the approximate location shown to the northeast of the project site.

Bighorn sheep movement in the Soda and Cady Mountains

South of the highway, the eastern end of the Soda Mountains falls within Mojave National Preserve and provides valuable water sources for wildlife from natural springs along the edge of soda dry lake. The Soda Mountains then parallel the highway to the southwest, providing consistent rugged terrain that leads to Cave Mountain, access to water from the Mojave River at Afton Canyon, and bighorn habitat in the Cady Mountains beyond. This well-connected habitat provides ideal conditions for bighorn movement back and forth between the southern Soda Mountains and the Cady Mountains, which each support populations of desert bighorn. GPS collars, genetic data, observed game trails, state records, and associated analyses confirm that inter-mountain movements like these occur regularly and are an integral part of desert bighorn ecology (Schwartz et al. 1986, Bleich et al. 1990, Epps et al. 2007, 2010, Dekelaita et al. 2023).

Desert bighorn in the southern Soda and Cady mountains likely once moved across the low valley that now contains I-15 in order to access the North Soda Mountains (Epps et al. 2005, 2013, Creech et al. 2014, Aiello et al. 2023). The loss of these movements has reduced the bighorn metapopulation's connectivity potential (Creech et al. 2014), with movement restoration expected to improve gene flow and population resiliency. Despite the Soda Mountain bighorn population's importance to region-wide connectivity, it is also a population at risk. The relatively low-elevation of the southern end of this range makes it susceptible to local extinction (Epps et al. 2004, 2010, Wehausen and Epps 2021). When animals are able to move freely between habitat patches, they gain access to additional resources and can immigrate to or recolonize vulnerable patches, which can mitigate extinction risks. The more well-connected a patch of habitat is, the more opportunities there are for inter-mountain movements to provide protective benefits. The South Soda Mountains are a prime example of this process in action, as the range was recolonized (ca. 2004) through immigration from nearby ranges. Because of the I-15 barrier to the north, a planned high-speed rail within the highway right of way, and an open OHV area to the south, these important inter-mountain movements are limited. The connections between the Soda Mountains and adjacent areas, and the planned overpass to restore access to the North Soda Mountains act to lessen the extinction risk of this population, as well as surrounding populations (Epps et al. 2006).

Ecological importance of bighorn movement corridors

The recolonization of the South Soda Mountains from the Cady Mountains demonstrates one of the key functions of inter-mountain movement for desert bighorn sheep. This process is termed "demographic" connectivity because the immigration of both males and females into an area can result in colonization or affect an existing population's growth rate (Creech et al. 2014). Populations that have disappeared or are dwindling in number can be recolonized or rescued by the arrival of immigrants from surrounding areas. Temporary inter-mountain movements can play equally important roles. Animals that visit nearby ranges can contribute to gene flow - male bighorn disproportionately contribute to this type of connectivity. Additionally, animals benefit from access to varied habitat patches because of the additional resources they provide at different time periods (Armstrong et al. 2016). Access to diverse habitat patches is particularly important in resource-limited environments, and in the face of ongoing climate change, where species' ability to access less stressful climate conditions will likely affect their future persistence (Epps et al. 2004, Robillard et al. 2015, Creech et al. 2020, Abrahms et al. 2021).

Decades of research on the connectivity of desert bighorn populations in this region has informed state and federal management strategies for this species. However, several integral studies including the Soda and Cady Mountain populations were conducted within 2013 – 2023, after the Soda Mountain Solar project was first proposed. In 2014, Creech et al. analyzed the contributions of individual movement corridors and habitat patches to the large-scale connectivity of the desert bighorn metapopulation within and adjacent to Mojave National Preserve (Figure 3). This study concluded that*:*

- Movement between the Soda and Cady Mountains ranked among the top five existing movement corridors with the largest contributions to region-wide connectivity
- The corridor linking the South and North Soda Mountains to the Avawatz Mountains beyond ranked highest among restorable corridors in terms of the action's benefits to demographic connectivity
- A management strategy focused on multiple connectivity-promoting actions, including restoring movement between the South and North Soda Mountains, could more *than double the connectivity metrics of the entire metapopulation examined in the study*
- Connectivity metrics were correlated with genetic diversity, indicating that actions that increase these metrics will likely lead to increased genetic diversity

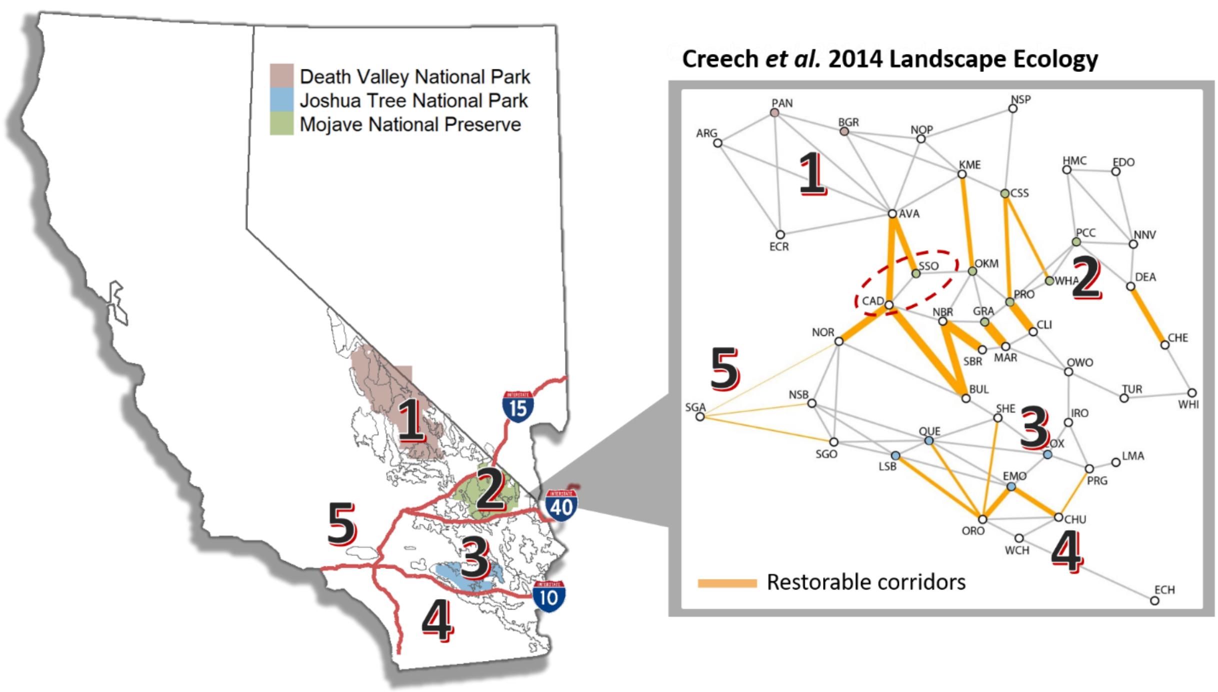

Figure 3. LEFT: The spatial extent of desert bighorn populations in California relative to major highway barriers that have divided populations into 5 distinct sub-units (excluding Peninsular bighorn populations that form a 6th distinct sub-unit). RIGHT: A network analysis of bighorn connectivity in the boxed sub-region found that movement between the Soda and Cady Mountains (circled by dashed red line) ranked among the top 5 existing corridors (grey lines) that contribute most to overall connectivity in the region. Fragmented, but restorable movement corridors are plotted as dark yellow lines with their width weighted by their potential contributions to connectivity if restored. The links plotted here represent the same genetic corridors plotted in Figure 1. Management actions that protect existing

movements, plus restore key movements across I-15, I-40, and I-10 (including re-connecting the North and South Soda Mountains with a crossing structure) could more than double the region's connectivity potential.

Protecting movement between the South Soda and Cady Mountains while restoring movement between the south and North Soda Mountains therefore has implications for desert bighorn health far beyond these two mountain ranges alone. The connectivity benefits extend throughout the Mojave Preserve and reach north in a stepping-stone fashion to Death Valley National Park. In light of bighorn sheep crossings of I-40 documented during recent research efforts (Epps et al. 2018, Dekelaita et al. 2023) and the planned overpass structures on I-15, there is potential to re-link three regions that have been fragmented by major highways (Figure 3). The state and NPS continues to prioritize these connectivity initiatives, as further research continues to highlight the benefits of protecting and maintaining well-connected bighorn habitat. These benefits include:

- Protection from climate extremes and increased population persistence (Epps et al. 2004)
- Diverse gene pools with the capacity for beneficial genes to spread faster (Epps et al. 2006, Creech et al. 2014, 2017)
- Resiliency in the face of disease outbreaks (Dugovich et al. 2023)
- Expanded access to varied habitat and elevation gradients (Aiello et al. 2023)

Sensitivity of bighorn to development and human activity

Bighorn sheep have complex responses to human activity and development that are informed by perceived risks and rewards. For example, bighorn will use developed areas that provide valuable resources such as grass fields in parks or golf courses, but avoid human disturbance (e.g., mountain biking trails) in areas with more typical habitat characteristics that may not be perceived as valuable enough to offset the risks (Lowrey and Longshore 2017). Dudek (2024) describes several studies that found negative bighorn responses to human activity including hiking, camping, vehicle use, and mountain biking (we will not re-describe those studies here as they are addressed in Appendix D2 of the project application, which can be accessed here). The increased vigilance and avoidance behaviors in the referenced studies indicate that bighorn perceive numerous human activities as a risk that warrants a behavioral response and at times, abandonment of otherwise suitable habitat.

The potential ecological impacts and significance of those impacts posed by this development hinges on how bighorn sheep respond to any human activity, noise, structures or lighting changes associated with the facility and its construction and decommission. These responses may not only be immediate (e.g., increased vigilance or fleeing in response to noise or current human presence), but gradual and long-lasting (e.g., increasing avoidance of the area over time and potential abandonment of previously used areas). Long-term studies conducted on pronghorn and mule deer in relation to a gas development of comparable size (2,360 acres) to Soda Mountain Solar suggest animals may not readily habituate to energy facilities as is often assumed (Sawyer et al. 2017, 2019). Sawyer et al. (2017, 2019) found evidence that both ungulate species responded to the development and used habitat further from well pads over a 15-year study (17-years for mule deer), even when most pads were in the production phase and involved less disturbance than periods of active drilling. Pronghorn showed a slightly more gradual response than mule deer that eventually led to consistent avoidance of well pads, animals spending less time within the larger study area surrounding the development, and more animals leaving the study area (Sawyer et al. 2019). The authors suggested that pronghorn may have initially had a variable response to the early stages of development, but once disturbance reached a threshold, pronghorn consistently avoided the area. At the end of the studies, mule deer and pronghorn were using areas that were an average of 913 m and 800 m further from well pads than pre-development years (respectively).

Few published studies directly assess large mammal responses to utility-scale solar energy facilities (USSE), though several studies are in-progress. Sawyer et al. (2022) found that pronghorn shifted behavior and habitat use up to 3 km away following construction of a USSE within a high-use seasonal range. This assessment, however, was based on a less-robust dataset than the gas development research previously mentioned. These combined studies still raise concerns about the potential indirect effects of large-scale energy development beyond the immediate footprint. Given that bighorn sheep in the Soda Mountains are already exposed to risks from the highway and OHV activity, we should consider the potential for an additional development to tip the scales of perceived risk such that bighorn consider abandoning formerly used areas.

Proximity of the proposed project to bighorn activity

If built, the proposed Soda Mountain Solar project would be the closest large-scale solar energy facility (≥ 1,000 acres) to occupied desert bighorn habitat in California (based on GIS data from the California Energy Commission [CEC]; California Department of Fish and Wildlife 2024). The solar facilities near Desert Center, CA are the only existing facilities of similar scale to come within one mile of preferred habitat with resident bighorn populations, but no data on bighorn movement pre/post facility construction are available for these populations. There is therefore limited data to draw on from other solar facilities to predict how bighorn populations will respond to a development of such scale.

Soda Mountain would be unique from existing facilities in that the project overlaps areas with documented bighorn activity. In their report, Dudek (2024) described GPS data from Soda Mountain bighorn provided by CDFW and show thirty locations recorded within the project footprint from 2013 -2023. There have likely been more occasions of bighorn using habitat within the footprint, considering that available collar data represent a small proportion of total movement on the landscape. As evidence of this, Panorama Environmental (2013) described observations of non-collared ewes foraging in the project area in a prior site assessment. The Dudek report included tracks from 50 animals with an average track length of 17.6 months – approximately 73 bighorn-years of movement. If we assume the bighorn population has been stable at 51-100 animals over the last 10 years as indicated by CDFW reports, the available GPS data represent approximately 7 -14% of the possible bighorn-years of movement throughout that period.

Even collared animals' movements are only partially documented; as collar location fix rates increase, the documented movement path becomes more precise relative to the true movement path of monitored individuals. Bighorn collars are often programmed with low fix rates to increase battery life at the expense of recording incomplete movement paths. Within the data summarized by Dudek (2024) are collars with the finest location rates to date used to identify suitable overpass locations (Aiello et al. 2023); points were collected at 30 min intervals when animals were within 1 km of the highway and at 1 hour intervals otherwise. These paths represent the most complete bighorn movements collected in this region, and suggest that bighorn may have crossed the project footprint multiple times within 3 years, despite only deploying collars with high fix rates on 8 animals within the project area (Figure 4). These paths also highlight the regular movement occurring adjacent to the project footprint that link the Soda and Cady Mountain populations.

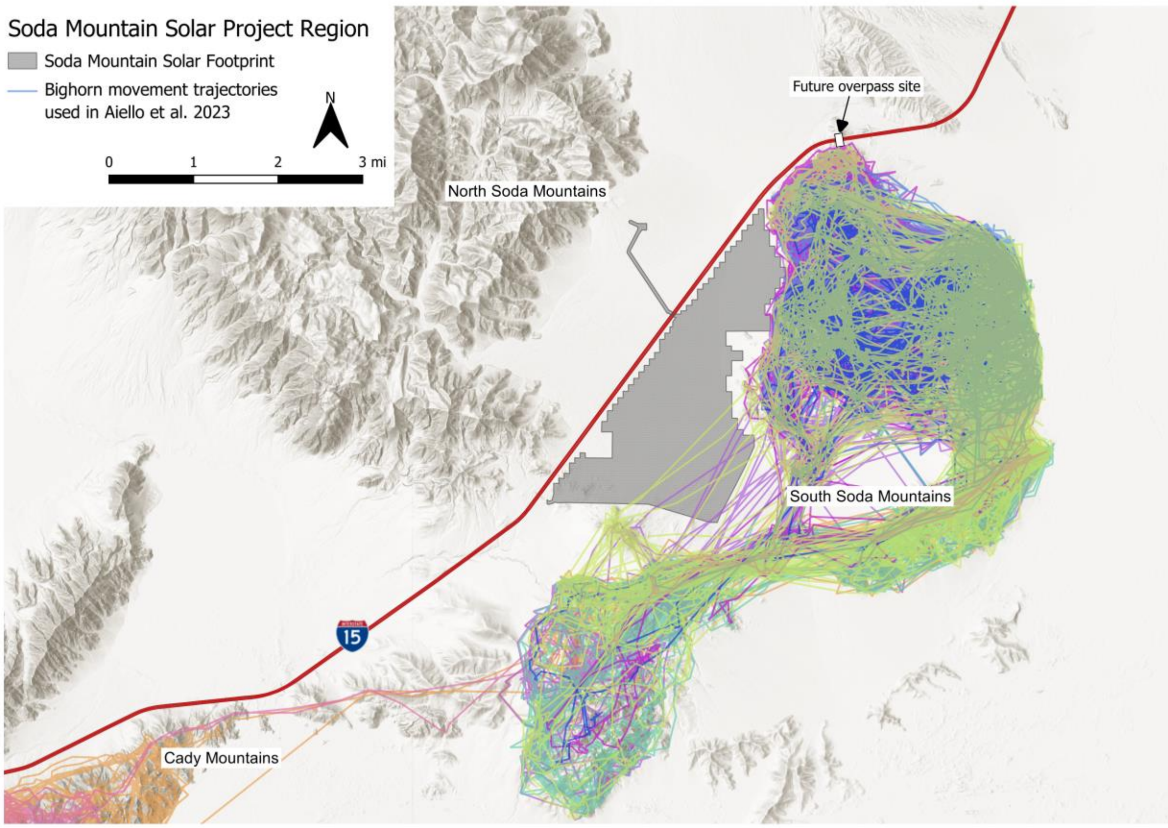

Figure 4. Movement paths documented from 8 bighorn sheep with collars set to collect points every 30-60 min depending on the animal's proximity to the highway. Raw GPS points were collected from October 2018 – November 2021 and were filtered for error and smoothed using a process described in Aiello et al. (2023) to create representative movement trajectories. Each animal's trajectory is plotted with a unique color.

When collared animal sample sizes are limited, movement simulations based on habitat preferences can help managers predict expected space use and have been used to estimate an individual or population home-range, predict movement in novel landscapes, and predict movement corridors (Signer et al. 2017, Whittington et al. 2022, Hofmann et al. 2023). Aiello et al. (2023) conducted such an analysis for desert bighorn populations near highways; the results for the Soda Mountains are plotted in Figure 5 and show the predicted movement patterns based on 1,200 simulated bighorn-years of movement. The Soda Mountain simulation results correlated strongly with bighorn activity observed in GPS data and even predicted a rare movement event. Though movement was simulated to reflect observed avoidance of I-15, the proximity of preferred habitat on the other side led to a simulated track crossing I-15 and moving into the North Soda Mountains along a similar path used by a collared female bighorn that successfully crossed I-15, but was not included in the Aiello et al. (2023) analysis. A separate independent roadkill event also occurred at this simulated crossing location, indicating that even movements that rarely occurred during simulation are still plausible for bighorn in this area.

The simulations classified areas within the proposed solar footprint as reachable habitat that is used with varied frequency. The footprint overlaps with 2,432 acres of habitat used during simulated movements (1.42% of the 171,188 acres used during simulations), with most areas used rarely to infrequently (Table 1). Documented use of these areas by bighorn have primarily occurred in winter when annuals first emerge at low elevations (Dudek 2024). These early-season forage sites comprise a valuable food and water source, particularly for females, as access to quality forage can influence early lamb survival (Wehausen 2005). Though this type of habitat may only be visited infrequently and comprises a small percentage of total habitat, it plays an important role in population performance. The south Soda Mountains are considered a range of marginal habitat quality (Weaver and Mensch 1970) and its low elevation and small size limit the timing and area of suitable forage; reducing access to any of these areas could have important effects on herd fitness and reproduction.

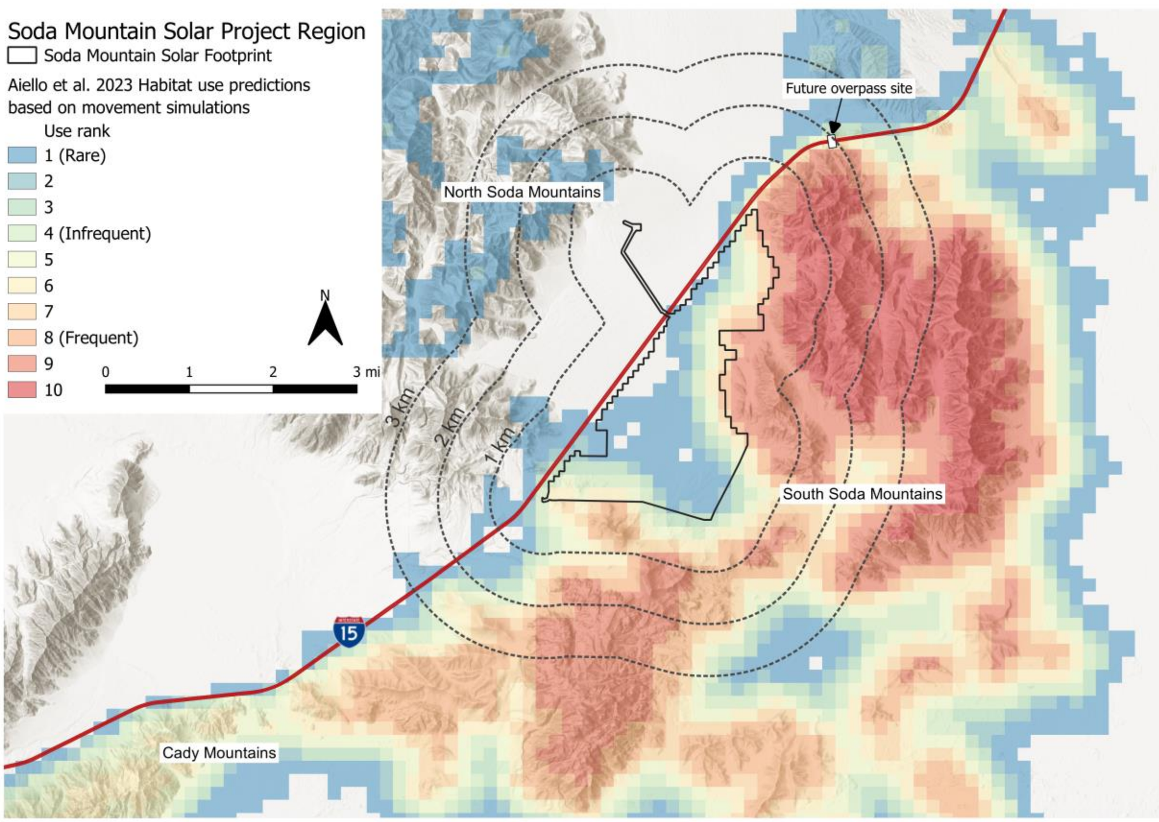

Figure 5. Predicted bighorn habitat use ranks near the Soda Mountain Solar footprint and 1, 2, and 3 km buffers around the footprint. Use ranks are based on movement simulations produced in Aiello et al. (2023) that reflect bighorn terrain preferences, typical movement velocities, home-ranging behavior (i.e., attraction to a core area of use) and avoidance of areas near the highway. Low ranks indicate that simulated movement rarely passed through a cell while high ranks indicate the cell was travelled through frequently.

Considering the studies described by Sawyer et al. (2017, 2019, 2022), we also calculated the area of predicted bighorn habitat that fell within a 1, 2 and 3 km buffer around the proposed project footprint (Figure 5, Table 1). We consider these buffers representative of additional areas that could be impacted by indirect effects if bighorn display avoidance of the development at a similar scale to that observed in other ungulate species. These avoidance behaviors may be triggered by either visual or auditory cues if bighorn perceive them as threatening. Notably, the future overpass site and predicted high-use habitat leading up to the site fell within the 2 km buffer. The footprint plus 1, 2 and 3 km buffered areas overlapped 2.83%, 3.24% and 3.59% of the 171,188 acres used during simulations respectively.

To identify areas at risk of visually-triggered impacts, we adjusted the total area of habitat within each buffer by cropping to areas that would have a clear view of at least 25% of the solar array (Figure 6; see Appendix A: Visibility Analysis for further details). Bighorn sheep behavior is shaped by the presence of risks and rewards on the landscape (Berger 1991, Bleich 1999, Papouchis et al. 2001, Dwyer 2004, Blum et al. 2023a, 2023b). Their keen eyesight and use of open habitat allows them to assess these factors at a distance to inform their movement decisions (Bleich 1999, Papouchis et al. 2001, Dwyer 2004, Berger et al. 2022). For example, in Sierra Nevada bighorn sheep, Berger et al. (2022) found evidence that a bighorn's decision to migrate to low-elevation winter range is partly informed by the habitat conditions that are visible from points used when on summer range. It is important to consider the potential effects of bighorn perception of these structures – if nearby animals perceive the facility as a risk, it could influence their decision to move toward the facility or adjacent areas.

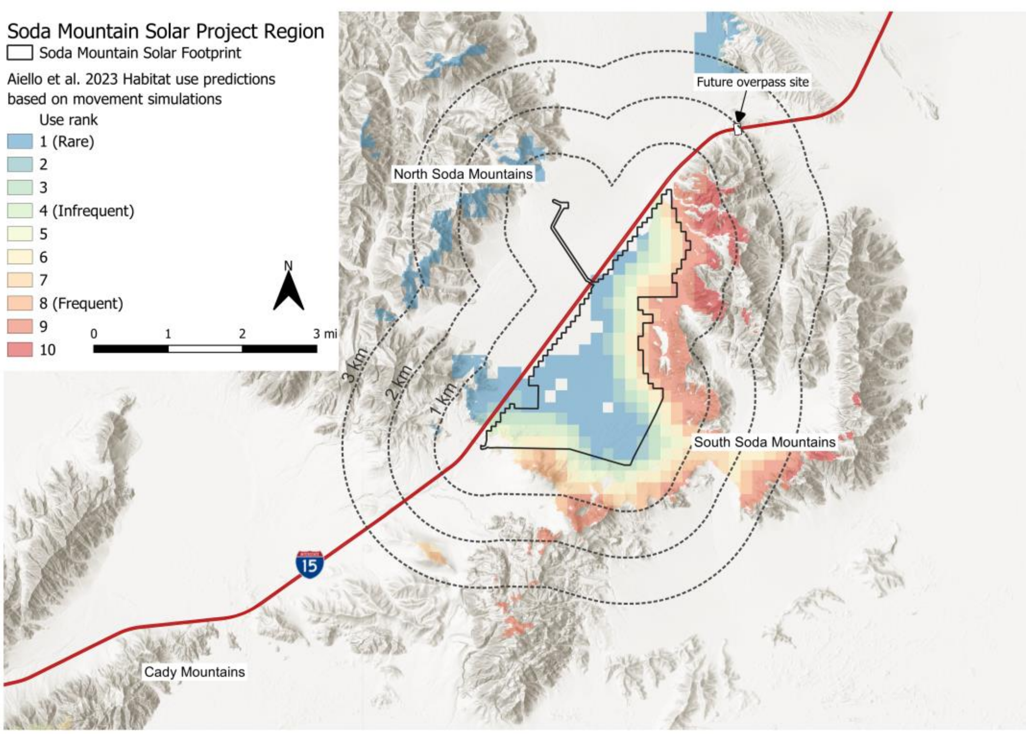

Figure 6. Predicted bighorn habitat use ranks (as described in Figure 5) subset to only include cells that had a view of at least 25% of the solar array based on a visibility analysis (Appendix A).

In addition to directly overlapping areas of occasional use, we estimated that the facility would be partly visible from 2,217 acres of adjacent habitat frequently used by bighorn in the Soda Mountains, with 1,597 of those acres having a view of ≥ 50% of the facility (Figure 8; Appendix A: Visibility analysis).

Table 1. Total area of predicted bighorn habitat that fell within the Soda Mountain Solar footprint or within a 1, 2, or 3 km buffer around the footprint. Use ranks are based on movement simulations produced in Aiello et al. (2023) that reflect bighorn terrain preferences, typical movement velocities, home-ranging behavior (i.e., attraction to a core area of use) and avoidance of areas near the highway barrier. Areas within the buffered areas were subset to only include cells that had a view of at least 25% of the solar array based on a visibility analysis (Appendix A).

	Acres within:			
Bighorn use rank	**footprint**	**1 km buffer**	**2 km buffer**	**3 km buffer**
1	986	1315	1551	1794
2	192	284	284	293
3	270	389	389	389
4	299	377	377	377
5	216	346	346	346
6	189	364	383	449
7	157	325	412	468
8	91	404	513	596
9	35	760	947	1088
10	0	283	346	346
Total	**2435**	**4846**	**5548**	**6145**

Risks posed by Soda Mountain Solar to bighorn conservation

The maximal negative impacts for bighorn in the region would not be from project-related direct mortality, but from indirect impacts to bighorn behavior. If the activity and structures associated with this development lead to bighorn avoiding areas within a 1-2 km buffer of the proposed footprint indefinitely, it could reduce or eliminate the rate of movement between the Cady and Soda Mountains as well as the area around the future overpass across I-15. Such an outcome would minimize the effectiveness of the state's investment in restoring connectivity via the overpass. We summarize the potential negative impacts below, under a high-, moderate- and low-impact scenario.

High-impact scenario: Bighorn indefinitely avoid existing and/or restorable movement corridors within the project's 2 km buffer

- Loss of the Soda Mountain to Cady Mountain movement corridor: If bighorn stop travelling the narrow corridor of habitat that connects these two ranges, the genetic connectivity of the larger bighorn metapopulation would be reduced (Creech et al. 2014) and the Soda and Cady Mountain populations would be further isolated. In the long-term, both populations would likely lose genetic diversity as a result (Epps et al. 2005, 2006).

- Increased risk of local extinction of the Soda Mountain population: The project directly removes accessible habitat for this population (Figure 5, Table 1), but if it also disrupts movement to the Cadys, it could further reduce accessible habitat as well as gene flow and future immigration (Epps et al. 2005; Aiello et al. 2023). The population would have fewer resources within an already low-quality habitat patch, a reduced rate of immigration to offset population losses, and a reduced rate of future recolonization.
- Compromised restoration of connectivity via the Soda Mountain overpass: If the Soda Mountain population is lost, or bighorn avoid the area near the overpass, the expected gains to bighorn metapopulation connectivity from the overpass would be completely negated; if the Soda Mountain population persists, but movement to the Cadys is lost, the benefits of the project would be significantly reduced.
- Financial and ecological losses associated with overpass failure: If impacts resulted in loss of the Soda Mountain population, or avoidance of the overpass area, the extensive time and costs to plan, design, and build this crossing structure (a $120 million investment) would be an immense waste to all stakeholders involved. The possibility that state government decision-making could undermine the success of the overpass, a legislatively-required conservation effort, stands to damage public perception of and support for wildlife crossing structures.
- Loss of bighorn-focused recreation opportunities: Loss of bighorn movement from the Soda to Cady Mountains or of the Soda population entirely could reduce hunting opportunities in the Cady Mountains hunt zone (animals collared in the Sodas have been successfully hunted in that zone, unpublished data). Such losses could also affect the available tag numbers allowed and any future expansion of hunting zones in this region. Mojave Preserve visitors to Zzyzx, CA benefit from prime bighorn-viewing opportunities that would also be lost with extinction of this population.

Moderate-impact scenario: Bighorn temporarily avoid existing and restorable movement corridors within the project's 2 km buffer, but eventually return to use current and restored corridors

- Reduced movement options within Soda Mountains: Movement between preferred habitat patches would be constrained to fewer possible routes, leaving bighorn less room to adjust movement in response to OHV activity or other disturbance from the south; movement rates between the Soda and Cady Mountains could be reduced as a result.
- Loss of forage areas within the project footprint: Forage within the footprint would be unavailable to bighorn, further reducing resource options in an already forage-limited low-elevation range; if additional forage becomes available via overpass use, the net benefit of the overpass would be reduced by the forage lost to the project.
- Delays in overpass discovery and success: Depending on the duration of area avoidance, and the timing of disturbance relative to construction of the I-15 overpass, the behavioral response could slow the discovery and adoption of the overpass. This could be politically and ecologically harmful if extensive delays in overpass success reduce support for future wildlife crossing structures. Though bighorn have been observed using disturbed landscapes,

we have little data to estimate what level of disturbance will be acceptable or the timeframes over which bighorn re-turn to abandoned areas.

Low-impact scenario: Bighorn behavior is not affected by the facility

- Reduced movement options between Soda and Cady Mountains: Impact as described above
- Loss of forage areas within the project footprint: Impact as described above

Proposed mitigation to reduce project impacts

In light of the research and spatial data discussed here and in Dudek 2024, as well as the conservation benefits at risk, we believe the distance between this large-scale development and habitat used by desert bighorn is insufficient. Dudek's bighorn study submitted with the development application (Appendix D2) suggested a 0.25 mi buffer beyond the edge of areas with 10% slope based on past CDFW recommendations (mitigation measure MM-BIO-23, Project Footprint Setback). The project application *Section 3.4 Biological Resources* notably does not include this recommended mitigation measure in the list of proposed mitigations (3.4.5 Mitigation Measures). We believe the proposed mitigation measures are inadequate to reduce the project impacts to "less than significant", particularly when considering the potential for the project to *interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors*. Further, based on the information provided in this assessment, we believe the recommended 0.25 mile buffer should be further extended to at least 1 km (0.62 mi), and ideally to 2 km (1.24 mi) to account for potential indirect effects and avoidance behaviors that may compromise essential bighorn movement corridors within this distance (see Figures 4-6).

Though a 0.25 mi buffer from 10% sloped habitat encompasses a majority of the habitat predicted as frequently used in Aiello et al. (2023), it does not protect intermittently used habitat (Figure 7). This buffer distance also does not provide protection from avoidance behaviors that may extend beyond the footprint up to distances observed in Sawyer et al. (2017, 2019, 2022). To reduce risk of the highest-impact scenario described above, a buffer distance between bighorn habitat and the project site would ideally be beyond the typical response distance of bighorn and other ungulates. Geist (1971) suggested that bighorn respond to predators at distances over 1 km away and so can likely process objects at this distance. We also found that most high quality habitat within view of the current footprint was within 1 km (Figure 6). Reducing the footprint so the project does not come within 1 km of 10% sloped areas would have the dual benefit of excluding structures from areas likely to receive intermittent bighorn use while providing a more robust buffer around movement corridors between Soda and Cave & Cady Mountains. It is unlikely that the structure would not be visible to bighorn at this distance, but perhaps would be far enough to reduce any perceived threats of activity associated with the development.

Creating a buffer between the facility and sloped habitat of 2 km, would be impossible within the project area, though there are reasons to support this measure for this and future USSE facilities. The movement analysis in Aiello et al. (2023) as well as extensive observations and research on desert bighorn in Southern California (Bleich et al. 1990; Epps et al. 2007; Creech et al. 2014; Dekelaita et al. 2023) indicate that desert bighorn are willing to use and cross flat areas that extend several km beyond 10% sloped terrain. In the Soda Mountains, it is clear that the preferred travel routes follow sloped terrain, but they are not the only routes that bighorn likely use. The presence of an active OHV area in the southern end of the range may already be constraining bighorn movement across other potentially suitable paths, or restricting movement to certain times of day or periods of the year. There has not been direct study of the effects of the OHV area on bighorn movement to assess existing impacts to this population, or how any future changes in OHV use (e.g., if OHV activity increases) may alter bighorn movement. If Soda Mountain Solar were built as proposed, bighorn travel options would be further constrained – with disturbance present on both sides of a vital movement corridor. For the future overpass effort to succeed and effectively reduce the long-term impacts of habitat fragmentation, this movement corridor must remain intact. Adding an additional development to an area already altered by OHV activity, a major highway, and a future high speed rail line seems like a reckless test of whether there is in fact a threshold level of disturbance needed before ungulates will abandon suitable habitat as suggested in Sawyer et al (2019). It is also counter-productive to the financial and time investments currently committed to increase habitat availability with the designed and planned overpass.

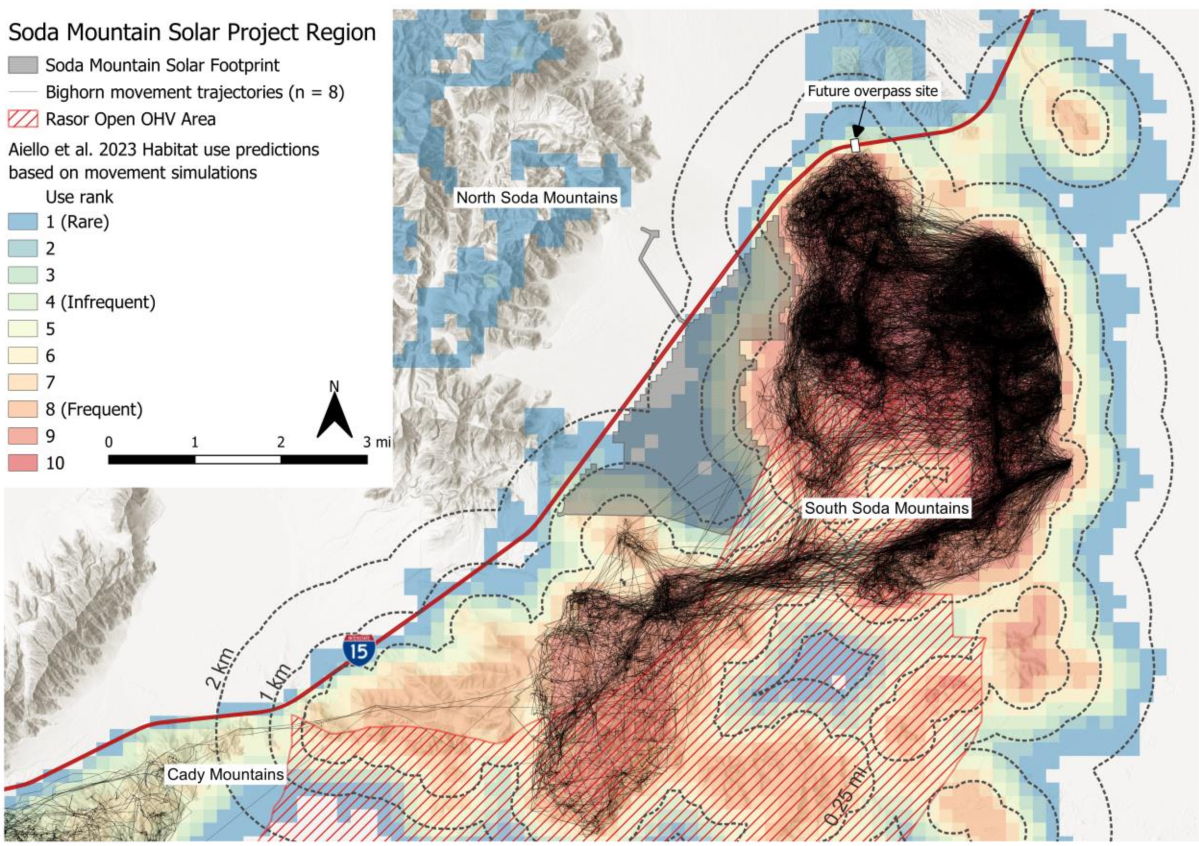

Figure 7. Soda mountain solar footprint relative to bighorn movement trajectories and predicted bighorn habitat from Aiello et al. (2023) and buffers around areas of 10% or greater slope of 0.25 miles (buffer recommended in Dudek 2024), 1 km and 2 km.

Conclusion

The data available to date indicate that the project as currently designed does not take enough measures to protect the ecological importance of this area to desert bighorn sheep in the region. The present uncertainty in how bighorn will react to the construction, structures, maintenance, and decommission associated with this project, and the huge investments made and planned for bighorn habitat and movement restoration suggest that more effort is needed to mitigate the risks. CDFW and Dudek (2024) previously recommended a 0.25 mi buffer and we show data that indicate this protects the most heavily used habitat, but that a 1 – 2 km (0.62 – 1.24 mi) buffer would be more suitable to also protect infrequently used habitat and reduce the potential for buffer effects that could compromise vital movement corridors for bighorn. The data presented here can be used to support footprint modifications based on the best-available science that would minimize impacts to the diverse set of resources and behaviors desert bighorn need to survive under current and future stressful conditions. We suggest that the footprint be reduced to increase the distance between the project and 10% sloped habitat, that any construction be delayed to allow for overpass construction and adoption by bighorn sheep, and that project impacts and needed mitigations be re-assessed once the overpass becomes functional.

Data Availability

Movement data from bighorn GPS collars should be requested from CDFW Bishop, CA office. The Soda Mountain simulated habitat raster (SODS_SumUD.tif) can be downloaded from: https://doi.org/10.6084/m9.figshare.21720533.v2. The Band 1, "With Highway" results from that geotiff file were used in all plots. The visibility layer and 0.25 mi, 1 km, 2 km, and 3 km habitat buffers will be attached as a .zip file to this assessment.

Acknowledgements

Funding for this assessment was provided by the National Park Service through the Pacific Northwest Cooperative Ecosystem Studies Unit (CESU) under cooperative agreement # P21AC11174.

Literature Cited

Abella, R. K., V. C. Bleich, R. A. Botta, B. J. Gonzales, T. R. Stephenson, S. G. Torres, and J. D. Wehausen. 2011. Status of bighorn sheep in California - 2010. Pages 54–68 Desert Bighorn Council Transactions.

Abrahms, B., E. O. Aikens, J. B. Armstrong, W. W. Deacy, M. J. Kauffman, and J. A. Merkle. 2021. Emerging Perspectives on Resource Tracking and Animal Movement Ecology. Trends in Ecology and Evolution 36:308–320.

Aiello, C. M., N. L. Galloway, P. R. Prentice, N. W. Darby, D. Hughson, and C. W. Epps. 2023. Movement models and simulation reveal highway impacts and mitigation opportunities for a metapopulation-distributed species. Landscape Ecology 38:1085–1103.

Armstrong, J. B., G. Takimoto, D. E. Schindler, M. M. Hayes, and M. J. Kauffman. 2016. Resource waves: Phenological diversity enhances foraging opportunities for mobile consumers. Ecology 97:1099–1112.

Berger, D. J., D. W. German, C. John, R. Hart, T. R. Stephenson, and T. Avgar. 2022. Seeing is be-leaving: perception informs migratory decisions in sierra nevada bighorn sheep (Ovis canadensis sierrae). Frontiers in Ecology and Evolution 10:46.

Berger, J. 1991. Pregnancy incentives, predation constraints and habitat shifts: experimental and field evidence for wild bighorn sheep. Animal Behaviour 41:61–77.

Bleich, V. C. 1999. Mountain sheep and coyotes: patterns of predator evasion in a mountain ungulate. Journal of Mammalogy 80:283–289.

Bleich, V. C., J. D. Wehausen, and S. A. Holl. 1990. Desert-dwelling mountain sheep: conservation implications of a naturally fragmented distribution. Conservation Biology 4:383–390.

Blum, M. E., K. M. Stewart, M. Cox, K. T. Shoemaker, J. R. Bennett, B. W. Sullivan, B. F. Wakeling, and V. C. Bleich. 2023a. Variation in diet of desert bighorn sheep (Ovis canadensis nelsoni): Tradeoffs associated with parturition. Frontiers in Ecology and Evolution 10.

Blum, M. E., K. M. Stewart, K. T. Shoemaker, M. Cox, B. F. Wakeling, T. E. Dilts, J. R. Bennett, and V. C. Bleich. 2023b. Changes in selection of resources with reproductive state in a montane ungulate. Movement Ecology 11:20.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildlife Monographs:3–174.

California Department of Fish and Wildlife. 2023. Caltrans, California Department of Fish and Wildlife and Brightline agree to build wildlife overcrossings for rail project. https://wildlife.ca.gov/News/Archive/caltrans-california-department-of-fish-and-wildlife-and-brightline-agree-to-build-wildlife-overcrossings-for-rail-project.

California Department of Fish and Wildlife. 2024. Draft conservation and management plan for bighorn sheep in California. California Department of Fish and Game, West Sacramento, CA, USA.

Creech, T. G., C. W. Epps, E. L. Landguth, J. D. Wehausen, R. S. Crowhurst, B. Holton, and R. J. Monello. 2017. Simulating the spread of selection-driven genotypes using landscape resistance models for desert bighorn sheep. PLoS ONE 12:1–26.

Creech, T. G., C. W. Epps, R. J. Monello, and J. D. Wehausen. 2014. Using network theory to prioritize management in a desert bighorn sheep metapopulation. Landscape Ecology 29:605–619.

Creech, T. G., C. W. Epps, J. D. Wehausen, R. S. Crowhurst, J. R. Jaeger, K. Longshore, B. Holton, W. B. Sloan, and R. J. Monello. 2020. Genetic and Environmental Indicators of Climate Change Vulnerability for Desert Bighorn Sheep. Frontiers in Ecology and Evolution 8:279.

Dekelaita, D. J., C. W. Epps, D. W. German, J. G. Powers, B. J. Gonzales, R. K. Abella-Vu, N. W. Darby, D. L. Hughson, and K. M. Stewart. 2023. Animal movement and associated infectious disease risk in a metapopulation. Royal Society Open Science 10.

Dudek. 2024. Desert bighorn sheep study: soda mountain solar project. A report prepared for California Department of Fish and Wildlife.

Dugovich, B. S., B. R. Beechler, B. P. Dolan, R. S. Crowhurst, B. J. Gonzales, J. G. Powers, D. L. Hughson, R. K. Vu, C. W. Epps, and A. E. Jolles. 2023. Population connectivity patterns of genetic diversity, immune responses and exposure to infectious pneumonia in a metapopulation of desert bighorn sheep. Journal of Animal Ecology:1–14.

Dwyer, C. M. 2004. How has the risk of predation shaped the behavioural responses of sheep to fear and distress? Animal Welfare 13:269–281.

Epps, C. W., R. S. Crowhurst, and B. S. Nickerson. 2018. Assessing changes in functional connectivity in a desert bighorn sheep metapopulation after two generations. Molecular Ecology 27:2334–2346.

Epps, C. W., D. R. McCullough, J. D. Wehausen, V. C. Bleich, and J. L. Rechel. 2004. Effects of climate change on population persistence of desert-dwelling mountain sheep in California. Conservation Biology 18:102–113.

Epps, C. W., P. J. Palsbøll, J. D. Wehausen, G. K. Roderick, and D. R. McCullough. 2006. Elevation and connectivity define genetic refugia for mountain sheep as climate warms. Molecular Ecology 15:4295–4302.

Epps, C. W., P. J. Palsbøll, J. D. Wehausen, G. K. Roderick, R. R. Ramey, and D. R. McCullough. 2005. Highways block gene flow and cause a rapid decline in genetic diversity of desert bighorn sheep. Ecology Letters 8:1029–1038.

Epps, C. W., J. D. Wehausen, V. C. Bleich, S. G. Torres, and J. S. Brashares. 2007. Optimizing dispersal and corridor models using landscape genetics. Journal of Applied Ecology 44:714–724.

Epps, C. W., J. D. Wehausen, R. J. Monello, and T. G. Creech. 2013. Potential impacts of proposed solar energy development near the South Soda Mountains on desert bighorn sheep connectivity.

Epps, C. W., J. D. Wehausen, P. J. Palsbøll, and D. R. McCullough. 2010. Using genetic tools to track desert bighorn sheep colonizations. Journal of Wildlife Management 74:522–531.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. University of Chicago press, Chicago, IL.

Hofmann, D. D., G. Cozzi, J. W. McNutt, A. Ozgul, and D. M. Behr. 2023. A three-step approach for assessing landscape connectivity via simulated dispersal: African wild dog case study. Landscape Ecology 38:981–998.

Hogg, J. T., S. H. Forbes, B. M. Steele, and G. Luikart. 2006. Genetic rescue of an insular population of large mammals. Proceedings of the Royal Society B: Biological Sciences 273:1491–1499.

Lowrey, C., and K. M. Longshore. 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 77:82–98.

Panorama Environmental Inc. 2013. Bighorn sheep survey results and analysis: soda mountain solar project. A report prepared for the Bureau of Land Management.

Papouchis, C. M., F. J. Singer, and W. B. Sloan. 2001. Responses of desert bighorn sheep to increased human recreation. The Journal of Wildlife Management 65:573–582.

Robillard, C. M., L. E. Coristine, R. N. Soares, and J. T. Kerr. 2015. Facilitating climate-change-induced range shifts across continental land-use barriers. Conservation Biology 29:1586–1595.

Sawyer, H., J. P. Beckmann, R. G. Seidler, and J. Berger. 2019. Long-term effects of energy development on winter distribution and residency of pronghorn in the Greater Yellowstone Ecosystem. Conservation Science and Practice 1:e83.

Sawyer, H., N. M. Korfanta, M. J. Kauffman, B. S. Robb, A. C. Telander, and T. Mattson. 2022. Trade-offs between utility-scale solar development and ungulates on western rangelands. Frontiers in Ecology and the Environment 20:345–351.

Sawyer, H., N. M. Korfanta, R. M. Nielson, K. L. Monteith, and D. Strickland. 2017. Mule deer and energy development—Long-term trends of habituation and abundance. Global Change Biology 23:4521–4529.

Schwartz, O. A., V. C. Bleich, and S. A. Holl. 1986. Genetics and the conservation of mountain sheep ovis canadensis nelsoni. Biological Conservation 37:179–190.

Signer, J., J. Fieberg, and T. Avgar. 2017. Estimating utilization distributions from fitted step-selection functions. Ecosphere 8.

Vu, R. K., R. Ianniello, J. Colby, E. Schaeffer, J. N. Sanchez, J. T. Villepique, L. E. Greene, and T. R. Stephenson. 2021. Status of bighorn sheep in California - 2021. Pages 87–95 Desert Bighorn Council Transactions.

Weaver, R. A., and J. L. Mensch. 1970. Desert bighorn sheep in southeastern San Bernardino County. California Department of Fish and Game, Sacramento.

Wehausen, J. D., V. C. Bleich, and R. A. Weaver. 1987. Mountain sheep in California: A historical perspective on 108 years of full protection. Transactions of the Western Section of the Wildlife Society 23:65–74.

Wehausen, J. D., and C. W. Epps. 2021. Population extinction and conservation planning for desert bighorn sheep in California. 56.

Western Association of Fish and Wildlife Agencies Wild Sheep Working Group. 2015. Records of wild sheep translocations - United Stated and Canada, 1922-present. USA.

Whiting, J. C., V. C. Bleich, R. T. Bowyer, and C. W. Epps. 2023. Restoration of bighorn sheep: History, successes, and remaining conservation issues. Frontiers in Ecology and Evolution 11.

Whittington, J., M. Hebblewhite, R. W. Baron, A. T. Ford, and J. Paczkowski. 2022. Towns and trails drive carnivore movement behaviour, resource selection, and connectivity. Movement Ecology 10:1–18.

Appendix A: Visibility Analysis

We conducted a visibility analysis in ArcGIS Pro to assess the potential visibility of the proposed development to bighorn sheep in the Soda Mountains. As we did not have access to a GIS layer depicting the exact position of the solar panel arrays, we created 1,000 regularly spaced points within the provided footprint and visually selected points expected to fall within the panel array footprint based on Figure 2-6 of the Chapter 2 Project Description submitted to the CEC. Using the selected array points as our observer features and a 30 m resolution digital elevation model (DEM), we ran the Visibility Spatial Analyst tool with the surface offset set to 1 m and the observer offset set to 6 m. The surface offset represents the height of a potential viewer on the landscape (in this case, a bighorn sheep) and the observer offset represents the height of the structure being observed. The solar array supports are expected to be 6 – 12m tall depending on site topography according to the Chapter 2 Project Description. The output raster was scaled so that each cell's value was the percentage of array points visible from that location (Figure 8).

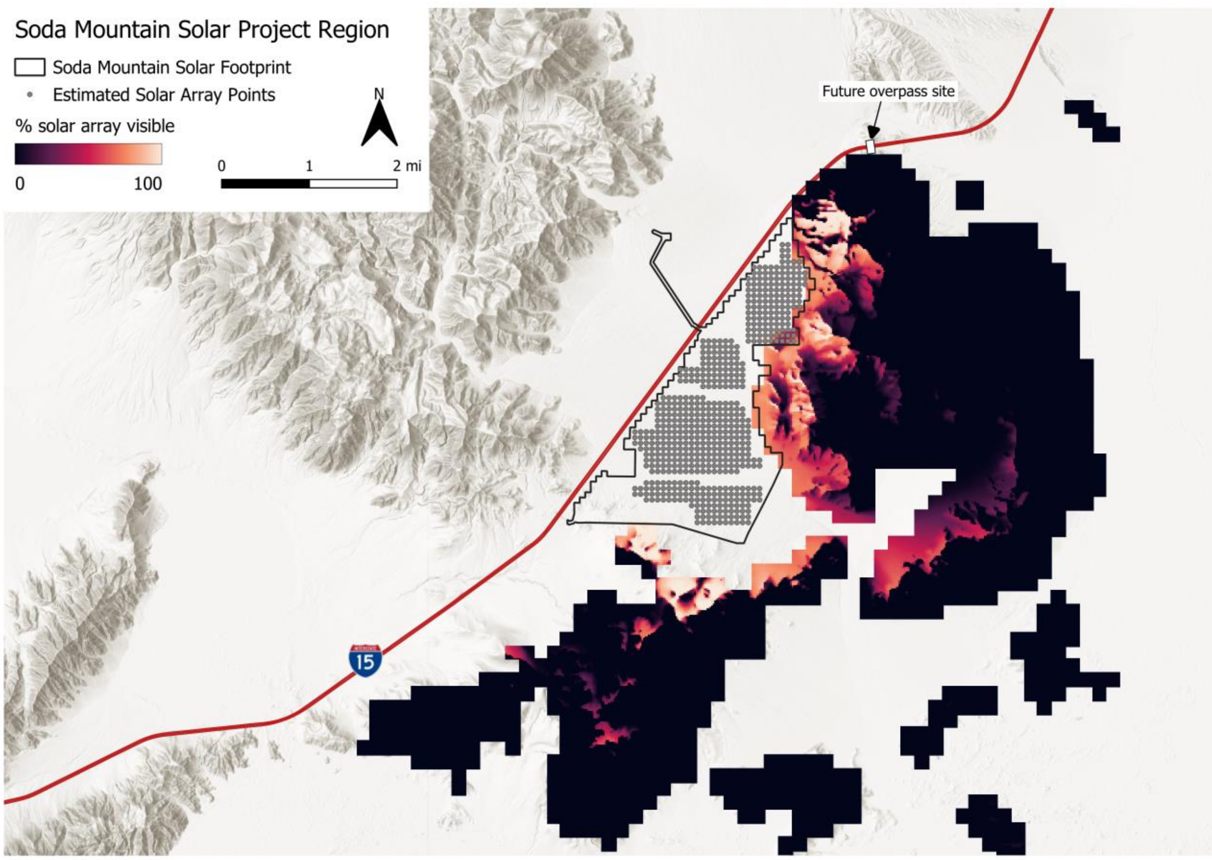

Figure 8. Results of the visibility analysis performed on a point array selected to represent the proposed solar panel configuration within the project footprint. The visibility raster was cropped and masked to grid cells identified as frequently used bighorn habitat in Aiello et al. 2023 (Figure 5).