CONSERVATION SCIENCE PARTNERS

**FINAL REPORT**

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# A landscape-level assessment of conservation values and potential threats in the Bears Ears National Monument

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## Introduction

Fundamental principles of systematic conservation planning (e.g., Margules and Pressey 2000) suggest that an ecologically functional protected areas network requires a sufficient land base, should protect a variety of habitats, and—perhaps most critically—needs to be resilient to ongoing climate change (Dawson et al. 2011), and interconnected (DeFries et al. 2007, Cumming et al. 2015). Yet, in the United States, as is the case in other places in the world, protected areas have rarely been selected to meet these criteria (Scott et al. 1993, Jenkins et al. 2015). Existing protected areas in the U.S. are likely insufficient to guard against the long-term loss of species and the habitats they require (Scott et al. 2001). Thus, there is a significant need to secure and connect protected areas to prevent further loss of biodiversity and preserve ecological functions in the face of climate change.

In the western U.S., vast areas of unprotected and undeveloped public land currently serve to enhance the ecological effectiveness of the U.S. protected areas network (Dickson et al. 2016). However, the expansion of energy development, mining, timber harvesting, and other extractive land uses threaten to fragment these areas, reducing their ecological function (Hansen and Defries 2007). These activities can also reduce the effectiveness of existing protected areas (e.g., Berger et al. 2014). Thus, careful selection of areas for conservation and protection that are based on the area's ecological significance and context is an important step for both maintaining and enhancing the existing protected areas network (Dickson et al. 2014, Watson et al. 2016). Moreover, there is a critical need to address the impacts and conservation implications of ongoing climate change on vulnerable public lands (Stein et al. 2014). Federal agencies are attempting to address this need through recent environmental initiatives, such as the strategy for improving the mitigation policies and practices of the Department of the Interior (Clement et al. 2014) and the National Fish, Wildlife, and Plants Climate Adaptation Strategy (National Fish, Wildlife, and Plants Climate Adaptation Partnership 2012). Federal land managers are particularly well positioned to work across jurisdictional boundaries and coordinate their climate adaptation planning strategies and activities among agencies and stakeholders (Olliff and Hansen 2016). Concomitantly, nongovernmental organizations and other partners must continue working with agencies to develop collaborative approaches for addressing climate change and adapting their own conservation and stewardship strategies.

In this context, the 1.35-million acre Bears Ears National Monument (BENM; Fig. 1) in southeastern Utah presents a significant opportunity to conserve key elements of ecological function within this region and across the western U.S. A recent study by Dickson et al. (2014) was designed to provide a sound scientific basis for conservation-based special designations in the western U.S., with an emphasis on unprotected, roadless Bureau of Land Management lands. Results from this study suggested that areas in the region that includes BENM were among the most important in the West, in terms of their conservation value. Here, we leverage input data and results

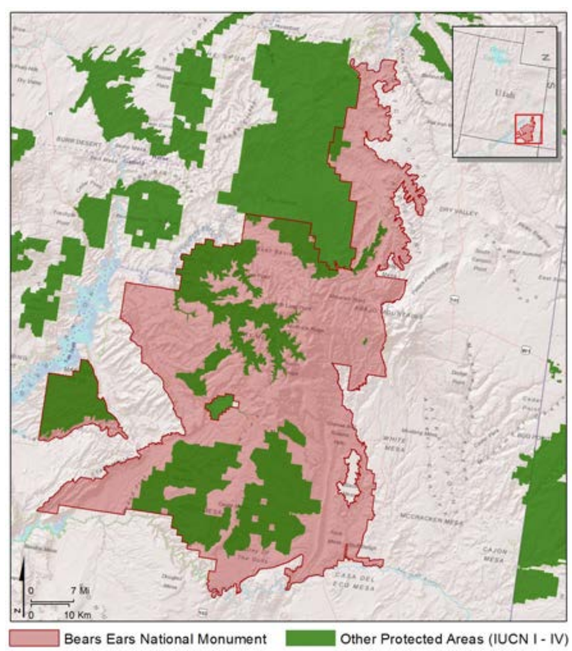



**Figure 1.** Bears Ears National Monument (BENM) and surrounding protected areas.

produced by this study, as well as other sources of readily available spatial data, to conduct an assessment of ecological features and values across BENM. We focused our assessment on information that highlighted the ecological importance, climate resilience, and ecological representativeness of BENM in a West-wide comparative analysis.

## Methods

### Assessing the conservation values and potential threats of the Bears Ears National Monument

For our assessment, we mapped and summarized twelve landscape-level indicators of ecological connectivity and intactness, biodiversity, resilience to climate change, remoteness and threats (detailed in Table 1 and Appendix A). Specifically, we used readily available spatial data layers and published methods to model two indicators of landscape connectivity and intactness: ecological connectivity (Dickson 2016) and ecological intactness (after Theobald 2013); six indicators of biodiversity: ecosystem type rarity (USGS 2011), lithological diversity (Soller and Reheis, 2004), rarity-weighted species richness (Chaplin et al. 2000; updated in 2013), vegetation diversity (Scott et al. 1993), mammal diversity and reptile diversity (Jenkins 2013); one indicator of remoteness: night sky darkness (NOAA 2012); one indicator of resilience to climate change: climate resilience (Hamann et al. 2015); and two indicators of threats and vulnerabilities to adverse change: mineral resource potential (USGS 2005) and oil and gas resource potential (Copeland et al. 2009, USDOI et al. 2008). Data for each indicator was generated at a 270-m pixel resolution. Although we focused our assessment on BENM, our indicator maps extended across all 11 western states, permitting comparisons between BENM and equivalently sized areas within these states, regardless of jurisdiction.

We determined the values of each of the indicators relative to the larger landscape using a simple scoring system based on percentile ranks. Specifically, the mean value of each indicator within BENM was compared to the distribution of means of a large ($n$ = 1000) random sample of areas across the 11 western states, including all jurisdictions. The size of the random samples was equivalent to the size of federal lands within the BENM. Scores ranged from 0 to 100. For example, a score of 98 for a given indicator would indicate that the mean value of that indicator in BENM was greater than or equal to 98% of the equivalently-sized random samples. Scores of 50 or higher suggest a relatively important indicator. We repeated this analysis using 10 of the 12 indicators (oil and gas and mineral resource potentials were omitted due to lack of data within national park boundaries) for each of seven well-known national parks, including Arches, Canyonlands, Glacier, Grand Canyon, Rocky Mountain, Yellowstone, and Yosemite. In each case, a given park was compared to a large ($n$ = 1000) random sample of areas equivalent in size to the park using the scoring system described above.

## Results and Discussion

Our analysis indicates that BENM contains multiple important conservation features and further highlights the need for special management of these values and resources.

***The BENM has exceptionally high potential to facilitate ecological connectivity and maintain ecological intactness.***

**Table 1.** Twelve indicators used to assess ecological and conservation values within BENM. See Appendix A for details on the source data and/or derivation of these datasets.

| Indicator | Data Source | Description |
|---|---|---|
| Ecological Connectivity | Dickson et al. (2016) | Model of ecological flow among existing protected areas within the 11 western states in order to quantify the ability of currently unprotected areas to enhance potential connectivity across the existing protected areas network. |
| Ecological Intactness | Theobald et al. (2016), Theobald (2013) | Characterizes the intensity and footprint of human modification across the West, based on 12 types of human activities. |
| Ecosystem Type Rarity | Ecological System Type, USGS (2011) | Areal extent of USGS GAP ecological system types. |
| Rarity-weighted Species Richness | NatureServe (2013) | Species rarity and irreplaceability that identifies sites that contain critically-imperiled or imperiled species with restricted distributions. |
| Lithological Diversity | Soller and Reheis (2004) | Published map of lithological units. Lithological diversity is a fundamental driver of both ecological and evolutionary processes that generate species diversity. |
| Vegetation Diversity | Ecological System Type, USGS (2011) | Estimate of ecological systems diversity at multiple spatial scales using USGS Gap Ecological Systems. |
| Mammal Diversity | BiodiversityMapping.org; Jenkins (2013) | Data of mammal species richness based on the range maps in the continental U.S. |
| Reptile Diversity | BiodiversityMapping.org; Jenkins (2013) | Data of reptile species richness based on the range maps in the continental U.S. |
| Night Sky Darkness | NOAA (2012) | Artificial nighttime lights observed via satellite. |
| Climate Resilience | Hamann et al. (2015) | Model of multivariate climate velocity to quantify the velocity (speed and direction) a species must migrate to persist in an area with the same climatic conditions, given projected changes in climate. |
| Mineral Resource Potential | USGS (2005) | Mineral and mine occurrence data from the USGS Minerals Resource Data System. |
| Oil & Gas Resource Potential | Copeland et al. (2009); USDOI et al. (2008) | Combination of two existing datasets to develop a west-wide representation of relative oil and gas resource potential. |

The maintenance of connectivity processes is one of the most important aspects of biodiversity and landscape-level conservation (Taylor et al. 1993, Noon et al. 2009). Considering all other western lands and jurisdictions, we observed exceptionally high values for ecological intactness and connectivity within BENM, scoring in the 92$^{nd}$ and 90$^{th}$ percentiles, respectively (Fig. 2, Maps 1 and 2). The BENM serves to facilitate the flow of multiple ecological processes, such as dispersal, migration, and gene flow (Dickson et al. 2016). Relatively unmodified landscapes in this region may be key to the movement of fundamental ecological processes between other protected areas and BENM (Dickson et al. 2016). BENM helps to build a true network of protected areas that enhance landscape connectivity (Krosby et al. 2010) and integrity (Theobald 2013), as well as the associated capacity for adaptation to future climate change (Heller and Zavaleta 2009; Dawson et al. 2011).

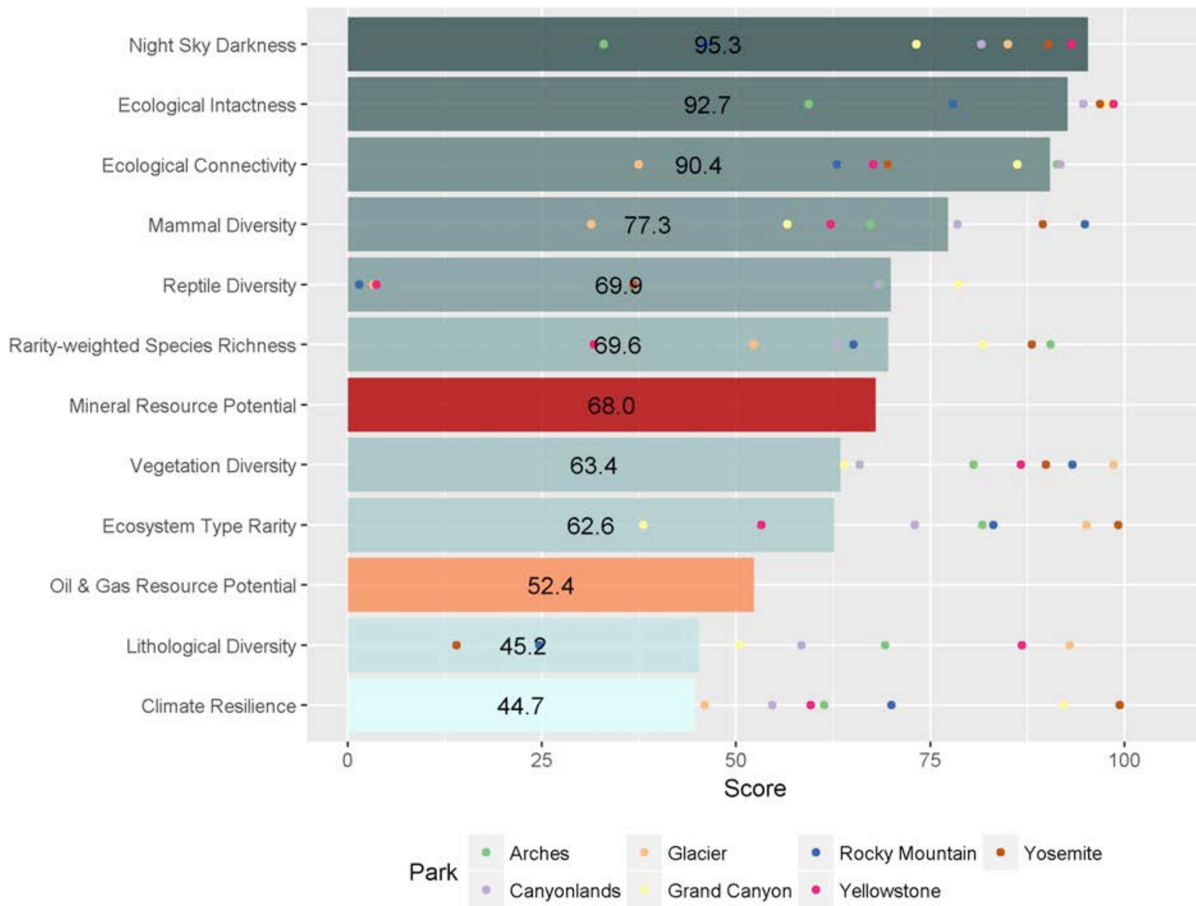



**Figure 2.** Scores received by BENM (bars) and seven national parks (dots) for each of the 12 ecological indicators by comparing them to a random set of equivalently-sized areas located across the 11 western states. Potential scores range from 0-100 (100 being highest). A score of 93 for a given indicator indicates that the mean value of that indicator in BENM or a given park was greater than or equal to the mean value in 93% of equivalently-sized random samples. A tabular summary of these scores is located in Appendix B.

***The BENM has exemplary scenic values in terms of night sky darkness and is one of the most remote landscapes in the western U.S., rivaling most large national parks.***

The BENM has some of the lowest levels of light pollution in the western US, scoring in the 95th percentile for night sky darkness. As a result, BENM is one of the darkest night skies of any equivalently sized areas in the western U.S. (Fig. 2, Map 1), suggesting it is one of the most remote landscapes in the western U.S. In North America, light emissions have historically increased at an estimated rate of 6% annually, resulting in a rapid increase in light pollution (Cinzano and Elvidge 2003). Considering our results, BENM may be one of the best landscapes in the U.S. to preserve remote environmental assets of both human and ecological significance (Watts et al. 2007).

***The ecological uniqueness and diversity of BENM contributes to its high value for biodiversity conservation.***

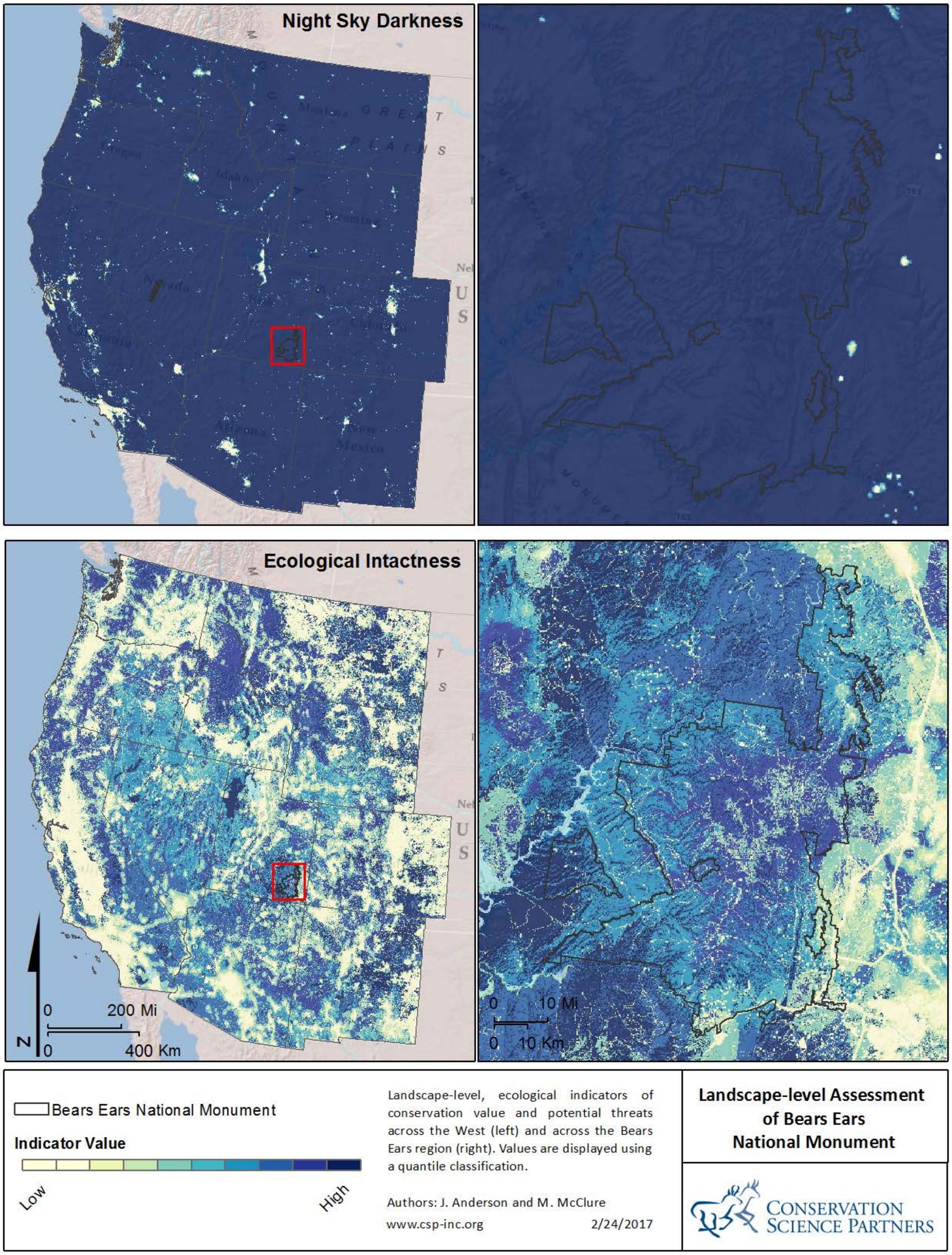
Our results indicate the West-wide importance of BENM to sustaining an imperiled but wide diversity of species comparable to most of the national parks we analyzed, given its high values with respect to mammal and reptile diversity, rarity-weighted species richness, and vegetation community diversity. The area scored in the 77$^{th}$ and 69$^{th}$ percentile for mammal and reptile diversity, respectively (Fig. 2, Maps 2 and 3). At the same time, BENM scored in the 69$^{th}$ percentile for rarity-weighted species richness, a relative measure of the concentration of rare and irreplaceable species for the conterminous U.S. (Chaplin et al. 2000) (Fig. 2, Map 4). Up to thirteen federally listed species potentially occur within BENM, and its boundaries include designated or proposed critical habitat for five listed species, including the Mexican spotted owl (*Strix occidentalis lucida*) and Southwestern Willow Flycatcher (*Empidonax trailii extimus*) (USFWS 2017). In addition, BENM scored in the 63$^{rd}$ percentile for vegetation community diversity, which includes a mix of significant Colorado Plateau, Rocky Mountain and Intermountain Basin vegetation types, and the 62$^{nd}$ percentile for ecosystem type rarity (Fig. 1, Maps 3 and 4). Our results point to the highly distinctive nature and irreplaceable value of this area with respect to rare and endemic species, as well as the diverse habitats they depend on.

***The BENM is vulnerable to adverse change associated with development of mineral, oil and gas resources.***

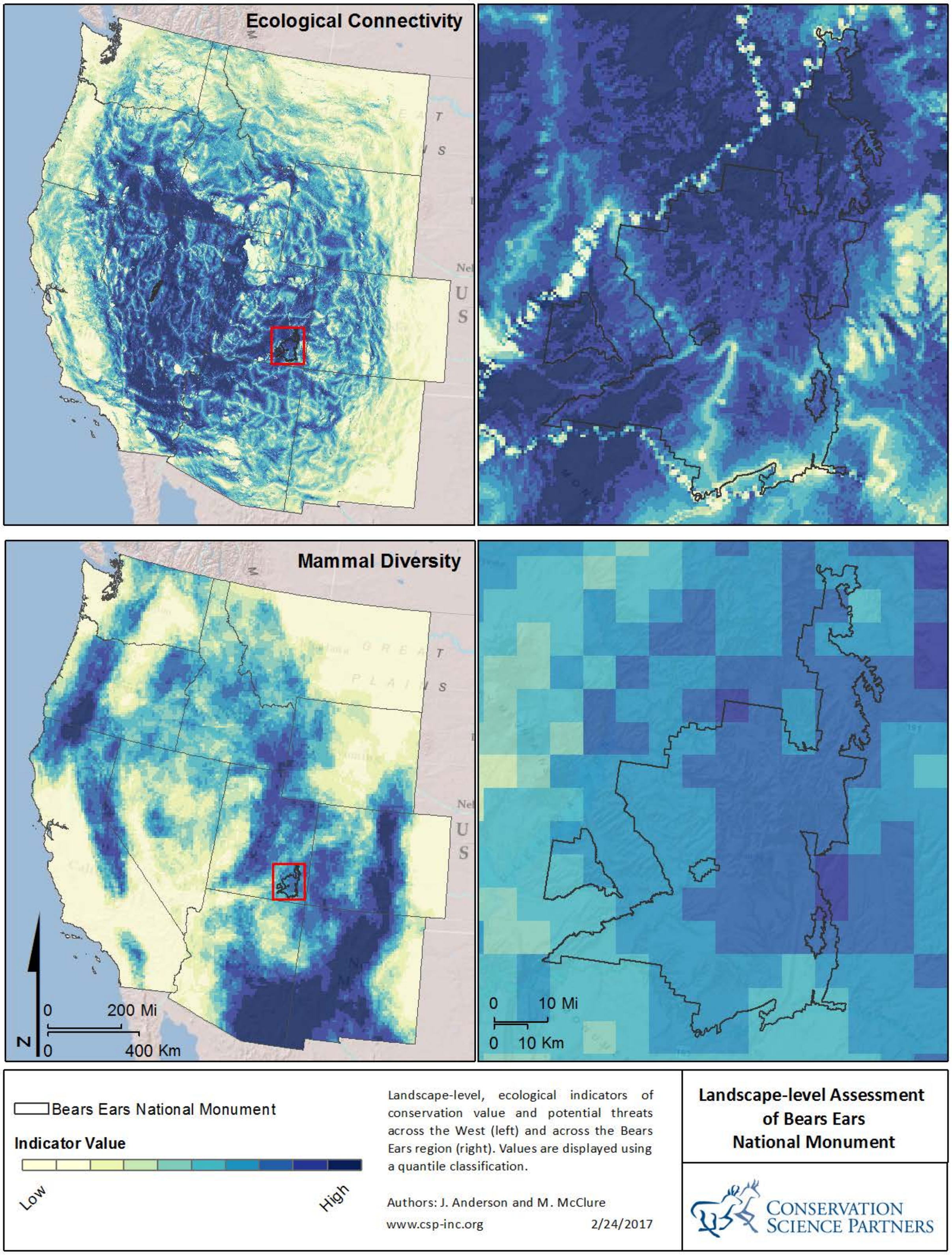
The BENM is vulnerable to mineral resource, and oil and gas resource development given high development potential, scoring in the 68$^{th}$ and 52$^{nd}$ percentile, respectively (Fig. 2, Map 6). Deposits of uranium, and to a lesser extent, vanadium and copper, occur within the BENM (USGS 2005). Historical mining of these resources in the lands surrounding the BENM have resulted in long-lasting legacies of soils, water, and air contamination, with serious impacts to human health (USEPA 2008). The potential impacts of energy developments such as wind, solar, and oil and gas on wildlife species are well documented (Northrup and Wittemyer 2013). In light of these potential impacts, special management attention will be needed to avoid negative effects on sensitive wildlife species and habitats, which may include habitat loss or fragmentation, direct mortality from vehicle or infrastructure collisions, changes in the fitness of individuals due to anthropogenic disturbances such as noise or light, or increases in predation mortality (Northrup and Wittemyer 2013).

## Conclusions

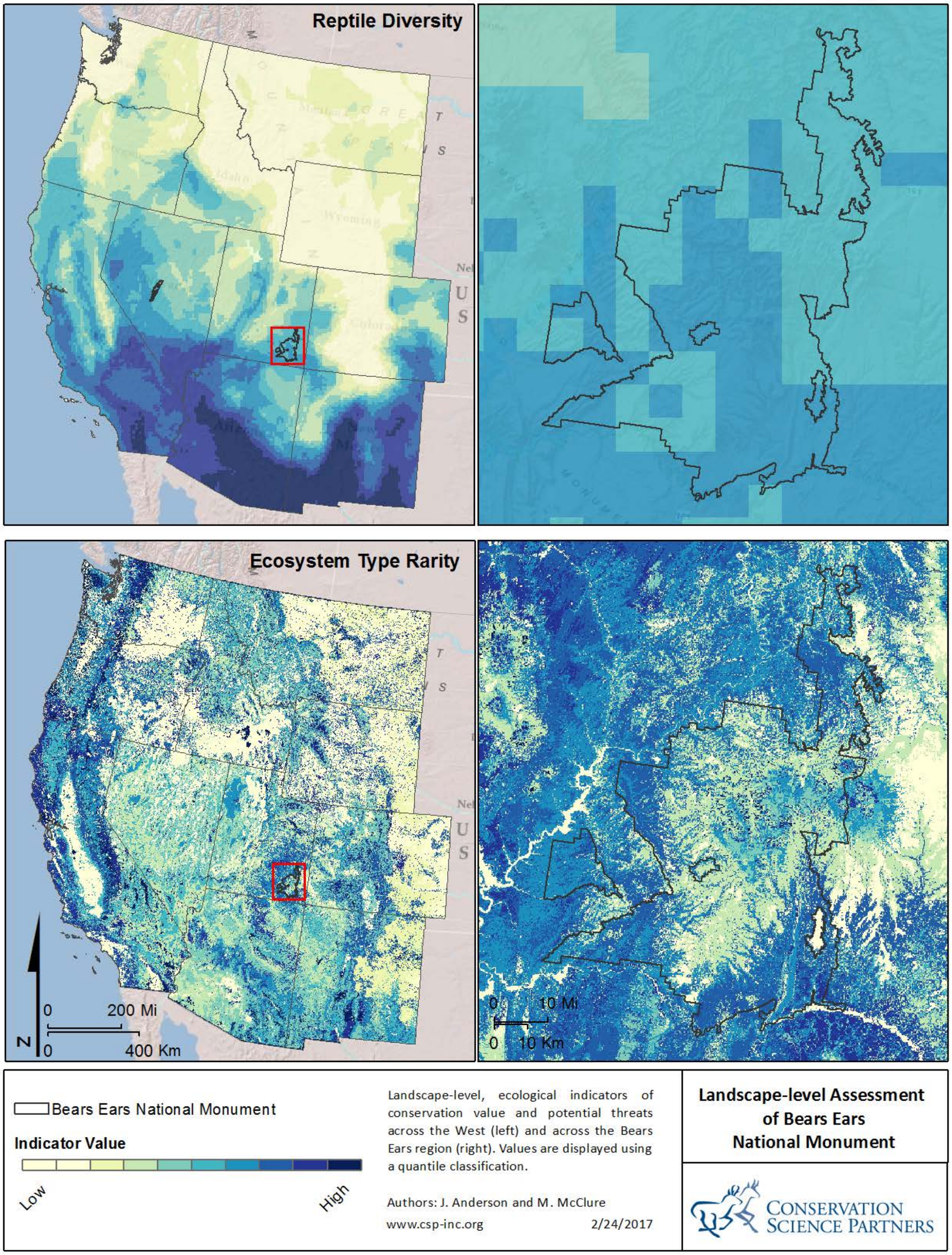
Our landscape-level assessment of BENM in a West-wide context highlighted the intrinsic value of the area with respect to multiple indicators of conservation value, namely ecological connectivity and intactness, remoteness and biodiversity. Our analysis further indicates that these values rival those found in many of the most well-known and larger national parks in the western U.S. Considering also the results of Dickson et al. (2014, 2016), BENM substantially enhances the existing network of protected areas in the face of climate change, while supporting fundamental ecological processes, such as habitat connectivity. The value of this area in sustaining the ecological function and large, contiguous landscapes that also support high levels of biodiversity should not be underestimated.



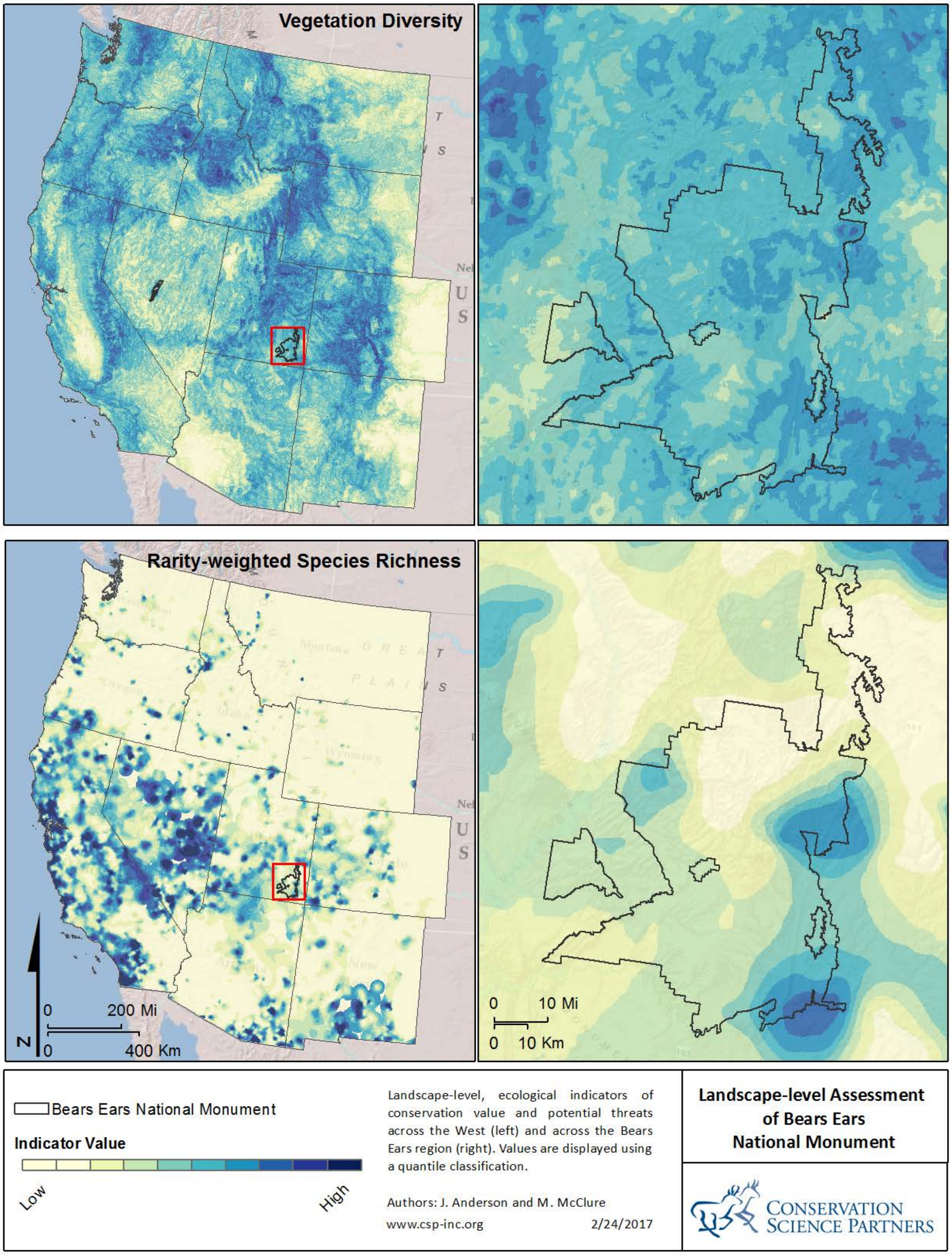

***Map 1.*** *Landscape-level, ecological indicators of* ***night sky darkness*** *(top) and* ***ecological intactness*** *(bottom).*



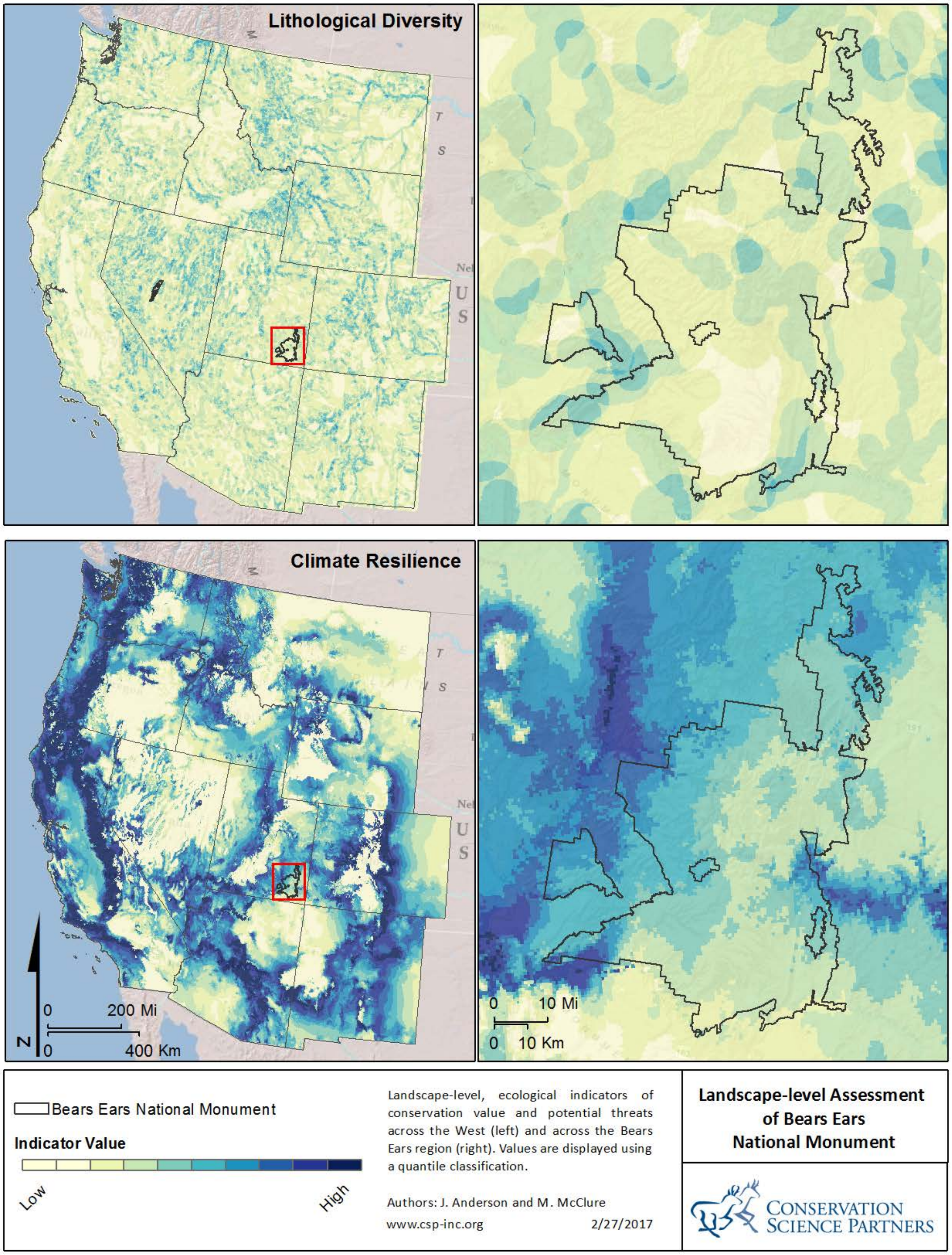

***Map 2.*** *Landscape-level, ecological indicators of* ***ecological connectivity*** *(top) and* ***mammal diversity*** *(bottom).*



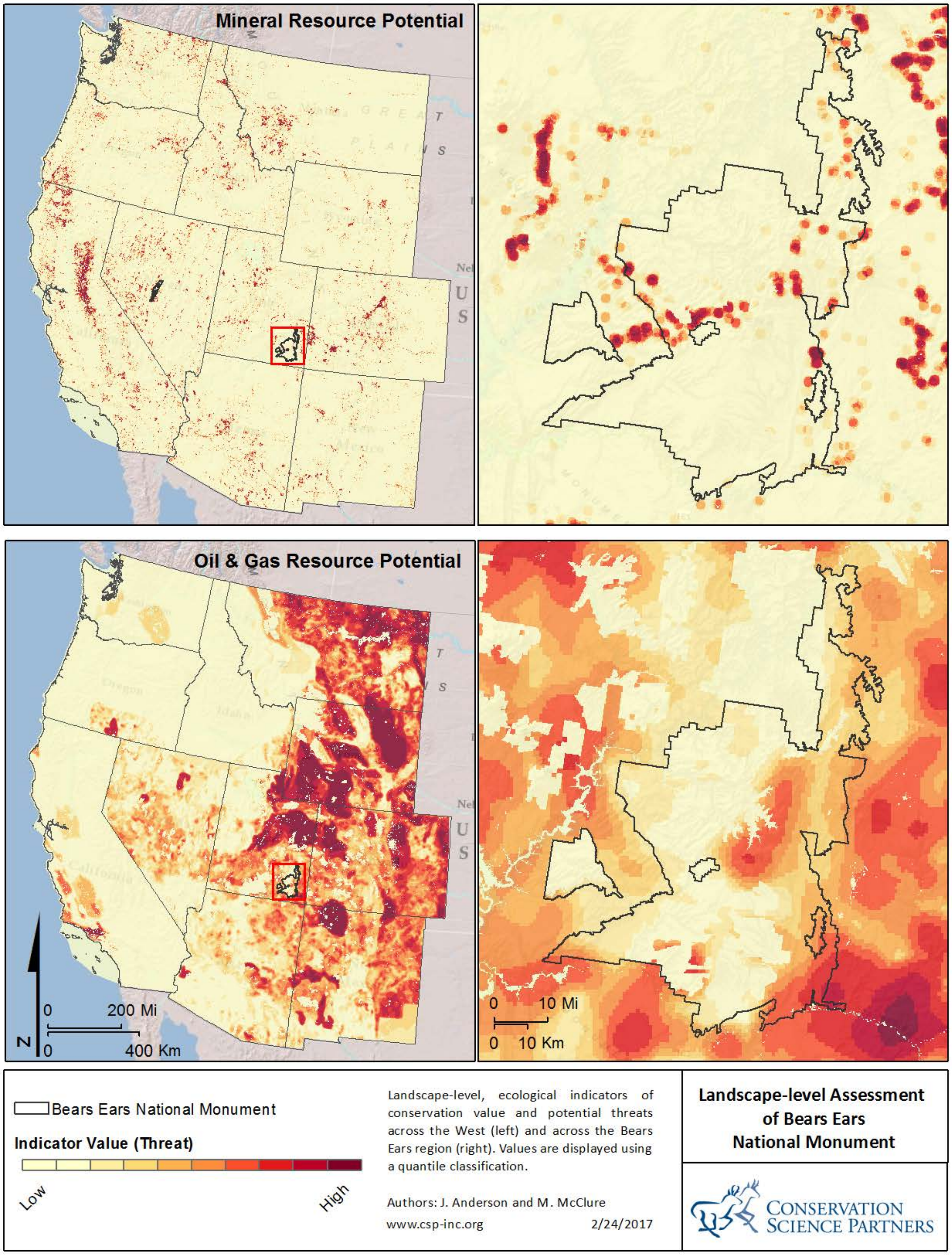

***Map 3.*** *Landscape-level, ecological indicators of* ***reptile diversity*** *(top) and* ***ecosystem type rarity*** *(bottom).*




***Map 4.*** *Landscape-level, ecological indicators of* ***vegetation diversity*** *(top) and* ***rarity-weighted species richness*** *(bottom).*




***Map 5.*** *Landscape-level, ecological indicators of* ***lithological diversity*** *(top) and* ***climate resilience*** *(bottom).*




***Map 6.*** *Landscape-level, ecological threat indicators of **mineral resource potential** (top) and **oil and gas resource potential** (bottom).*

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## Appendix A. Derivation of Indicators

Descriptions of source data (and original pixel resolution) and derivation methods for twelve indicators used to assess ecological characteristics within BENM.

**Rarity-weighted Species Richness**

Rarity-weighted species richness provides a relative measure of the concentration of rare and irreplaceable species across the US (Chaplin et al. 2000). High rarity-weighted species richness is often indicative of the presence of numerous endemic species and/or sites that contain critically-imperiled or imperiled species with restricted distributions (i.e., G1-G2 –ranked species). These sites are essential for maintaining species diversity, particularly rare, sensitive, and irreplaceable species. We used NatureServe's rarity-weighted richness index (refreshed 2013) 1-km resolution data layer as an indicator of species rarity and irreplaceability (see Chaplin et al., 2000 for references and description of methods). Additional information on this metric is available here.

**Ecosystem Type Rarity**

Areas with high ecological system rarity are those that support rare, unique, or irreplaceable natural systems. These systems are likely to consist of species that are rare, unique, or irreplaceable. Ecological systems are defined as "groups of plant community types that tend to co-occur within landscapes with similar ecological processes, substrates and/or environmental gradients" (Comer et al. 2003), thus they incorporate physical components such as landform position, substrates, hydrology, and climate in addition to vegetation. To characterize ecological system type rarity, we calculated the areal extent of USGS GAP ecological system types at 30-m resolution (USGS 2011), then normalized the values based on the maximum value so that they ranged from 0 (least rare) to 1 (most rare).

**Ecological Systems (Vegetation) Diversity**

Diverse ecological systems, defined as "groups of plant community types that tend to co-occur within landscapes with similar ecological processes, substrates and/or environmental gradients" (Comer et al. 2003), provide a variety of habitats essential for maintaining species diversity (Noss 1990). Ecological system diversity may stem from the presence of diverse vegetation types, strong elevation gradients, ecotonal transitions among biome types, and/or interspersion of unique water-associated communities, such as wetlands, marshlands, meadows, and riparian zones. We followed methods in Theobald et al. (2015) to derive an estimate of ecological systems diversity at multiple spatial scales, equivalent to average sizes (1.2 – 115.8 km radii) of HUC 4-16 watersheds and using the Shannon-Weaver Equitability Index. We used the 30-m resolution USGS Gap Ecological Systems Units (2011) as the basis for calculating ecosystem diversity and assigned null values to all developed and invasive species land cover types prior to running the analysis, so that these lands would not contribute toward the diversity calculation.

**Night Sky Darkness**

Places with high night sky darkness have low levels of light pollution, which confers high scenic value. The absence of night light pollution is also likely to indicate low levels of human activity and disturbance in these areas. We used an existing dataset representing the presence of artificial nighttime lights at 740-m resolution observed via satellite (NOAA 2012).

**Ecological Intactness**

Ecologically intact landscapes are those with minimal to no influence from human activities that are thereby able to support natural evolutionary and ecological processes (Angermeier & Karr 1994; Parrish

et al. 2003). These landscapes are able to support and maintain communities of organisms that have species composition, diversity, and functional organization comparable to those of natural habitats within a region (Parrish et al. 2003). Degree of human modification of a landscape thus represents the inverse of ecological intactness. We used an updated version (Theobald et al. 2016) of a human modification model derived at 30-m resolution (Theobald 2013), which characterizes the intensity and footprint of human modification across the West, based on 12 parsimonious types of human activities.

**Lithological Diversity**
Lithological diversity, or diversity of soil parent materials, is a fundamental driver of both ecological and evolutionary processes that generate species diversity (Lawler et al. 2015). Areas with high lithological diversity offer heterogeneous conditions to support diverse vegetation types that thrive on different substrates. Lithological diversity is closely related to geological diversity (above), but the two indicators are derived from different datasets. To characterize lithological diversity we converted a published map of lithological units (1:5,000,000) (Soller & Reheis 2004) to a 270-m grid and calculated the number of unit types within a 65,000-acre moving window.

**Ecological Connectivity**
Areas with high ecological connectivity have high capacity to facilitate natural processes such as dispersal, migration, and gene flow (Dickson et al. 2016). Fundamental principles of systematic conservation planning (e.g., Margules & Pressey 2000) suggest that an ecologically functional system of protected areas (PAs) needs to be interconnected (DeFries et al. 2007; Cumming et al. 2015), and maintaining ecological connectivity is the most frequently recommended strategy for maintaining biodiversity in a changing climate (Heller & Zavaleta 2009). We derived a model and 270-m resolution map of ecological flow among existing protected areas within the 11 western states in order to quantify the ability of currently unprotected areas to enhance potential connectivity across the existing protected areas network. This connectivity model was designed to inform land use planning and policy efforts concerned with the maintenance of connectivity processes (e.g., migration and dispersal, gene flow) for multiple terrestrial species simultaneously. Specifically, we used a model of human modification (Theobald 2013) to estimate landscape resistance (see Krosby et al. 2015) and concepts from electronic circuit theory (McRae et al. 2008) to estimate the flow (as measured by current density) of ecological processes across the region.

**Mammal and Reptile Species Diversity**
We used published data on mammal and reptile species richness to quantify vertebrate species diversity. These data are based on overlap among species range maps in the continental U.S. represented at 10-km resolution, as tabulated by Jenkins et al. (2013).

**Climate Resilience**
Areas with high climate resilience are those that contribute to the ability of species to adapt to climate change through both local and long-distance movements. Climate velocity represents the speed and direction a species must migrate to keep pace with shifts in climate conditions to which they are suited, given projected changes in climate (Loarie et al. 2009). Low velocities indicate that the climate conditions currently occupied by a given species are projected to occur nearby in the future, whereas high velocities indicate that the species will have to migrate longer distances more quickly to keep up with changing climate. Places with low climate velocity, if left intact, may function as important strongholds of species diversity under changing climate, and thus have high climate resilience. We used a published model of multivariate climate velocity (Hamann et al. 2015) derived at 1-km resolution to quantify potential resilience to climate change. The estimate was based on the averages of model

projections from an ensemble of 15 CMIP5 models and the Representation Concentration Pathway (RCP) 8.5 scenario (IPCC: Pachauri et al. 2014), and included 11 biologically-relevant climate metrics related to changes in both temperature and precipitation between 1996 and 2055.

**Potential for Oil & Gas Development**

The potential impacts of oil and gas developments on wildlife species are well documented (Northrup & Wittemyer 2013). In light of these potential impacts, special management attention will be needed to avoid negative effects on sensitive wildlife species and habitats, which may include habitat loss or fragmentation, direct mortality from vehicle or infrastructure collisions, changes in the fitness of individuals due to anthropogenic disturbances such as noise or light, or increases in predation mortality (Northrup & Wittemyer 2013). We combined two existing datasets to develop a west-wide representation of relative oil and gas resource potential at 1-km resolution because no comprehensive dataset existed for the entire study extent. These included 1) a published predictive model of relative oil and gas resource potential that was conditioned on a suite of geophysical variables and oil and gas well production data (Copeland et al. 2009), and 2) spatial data from the Energy Policy and Conservation Act (EPCA) Phase I-III inventories of oil and gas resources (USDOI et al. 2008), which provides coarse- scale estimates of total oil and gas densities within specific focal basins and extrapolates estimates to unstudied basins. Because the former dataset provided continuous and finer-scaled data, and because this model included a validation, we used this dataset preferentially; however, it excluded California and Washington, as well as parts of New Mexico, Idaho, Montana, and Oregon. We supplemented these gaps, which, with the exception of some areas in California and New Mexico, had low oil and gas resource potential, using the EPCA data. Because the EPCA data characterizes oil and gas potential separately, we generated raster surfaces for each of these resources individually, and as with the solar datasets, took the maximum value of the two at each pixel to represent the resource value (oil vs gas) that was greatest, then max-normalized the result. We visually compared the Copeland et al. (2009) and composite EPCA datasets and verified that areas of maximum resource potential were consistent between them. We then replaced null values in the Copeland et al. (2009) dataset with the composite EPCA data (both max-normalized on a scale of 0 to 1) to generate a wall-to-wall estimate for the entire study extent. Finally, we assigned a value of 0 to open waters, developed (urban) land cover types (USGS 2011), and those classified as protected areas (IUCN I-IV, USGS 2012), because development is unlikely to occur in these areas.

**Mineral Resource Potential**

Extraction of mineral resources has both direct and indirect impacts on organisms and their environments, including physical alteration of landform, drainage, and soil conditions, as well as alteration of chemical conditions through waste runoff (Ratcliffe 1974). We used mineral and mine occurrence data from the USGS Minerals Resource Data System (USGS 2005) to characterize minerals resource potential. We generated a binary raster surface based on the presence/absence of minerals occurrences within each 270 m cell and smoothed the data by calculating a focal mean based on a 2-cell (540 m) circular radius around each occurrence. We assigned a value of 0 to open waters, developed (urban) land cover types (USGS 2011), and those classified as protected areas (IUCN I-IV, USGS 2012), because development is unlikely to occur in these areas.

## Appendix B. Indicator Scores for Bears Ears and Other Large National Parks

**Table B1**. Scores received by BENM and seven national parks for each of 12 ecological indicators by comparing them to a random set of equivalently-sized areas located across the 11 western states. Potential scores range from 0-100 (100 being highest). A score of 93 for a given indicator indicates that the mean value of that indicator in BENM or a given park was greater than or equal to the mean value in 93% of equivalently-sized random samples. Note that sufficient mineral and oil and gas resource potential data were not available for national parks so scores are omitted for these values.

| Indicator | Bears Ears | Arches | Canyonlands | Glacier | Grand Canyon | Rocky Mountain | Yellowstone | Yosemite |
|---|---|---|---|---|---|---|---|---|
| **Size (million acres)** | **1.35** | 0.08 | 0.33 | 1.01 | 1.20 | 0.27 | 2.20 | 0.75 |
| **Ecological Connectivity** | **90.4** | 91.3 | 91.8 | 37.5 | 86.2 | 62.9 | 67.6 | 69.5 |
| **Ecological Intactness** | **92.7** | 59.3 | 94.7 | 98.4 | 97.9 | 77.9 | 98.6 | 96.9 |
| **Ecosystem Type Rarity** | **62.6** | 81.7 | 73.0 | 95.1 | 38.1 | 83.1 | 53.3 | 99.2 |
| **Rarity-weighted Species Richness** | **69.6** | 90.5 | 63.0 | 52.3 | 81.8 | 65.1 | 31.7 | 88.1 |
| **Lithological Diversity** | **45.2** | 69.2 | 58.4 | 93.0 | 50.5 | 24.7 | 86.8 | 14.0 |
| **Vegetation Diversity** | **63.4** | 80.6 | 65.9 | 98.6 | 63.9 | 93.3 | 86.7 | 89.9 |
| **Mammal Diversity** | **77.3** | 67.2 | 78.5 | 31.4 | 56.6 | 94.9 | 62.1 | 89.5 |
| **Reptile Diversity** | **69.9** | 68.7 | 68.3 | 3.3 | 78.6 | 1.5 | 3.7 | 36.8 |
| **Night Sky Darkness** | **95.3** | 33.0 | 81.6 | 85.0 | 73.2 | 46.0 | 93.2 | 90.2 |
| **Climate Resilience** | **44.7** | 61.3 | 54.7 | 46.0 | 92.2 | 70.0 | 59.6 | 99.4 |
| **Mineral Resource Potential** | **68.0** | | | | | | | |
| **Oil & Gas Resource Potential** | **52.4** | | | | | | | |