Is Artificial Light a Threat to Starry Skies over Bears Ears National Monument?

Megan O'Brien '25 and Cyndy Hines

Abstract:

Bears Ears National Monument, known for breathtaking landscapes and starry skies, plays a significant role in the socio-political context of Southeast Utah. Increasing light pollution from population growth of bordering towns and land use activities (e.g., rural land development, oil and methane extraction) are cause for concern for the Indigenous people of Bears Ears National Monument whose cultures and life-practices are tightly tied to the cosmos. The State of the Rockies Project worked with The Inter-Tribal Coalition of Bears Ears during the summer of 2024 to gain insight into the pervasiveness of light pollution in and around the area. The coalition is made up of five tribes—the Hopi Tribe, the Navajo Nation, the Ute Mountain Ute Tribe, the Zuni Tribe, and the Ute Indian Tribe. The group is considering a dark skies designation as community growth and a steady uptick in visitation to the Monument threatens their ancient connection to the stars. The State of the Rockies Public Lands Team took multiple trips to Southeast Utah to collect artificial light data and interview tribal members and locals concerned about protecting the area from the threat of rural development and growing popularity of the Monument. In this study, VIIRS data was used to identify areas of high and low artificial light readings in three towns located near Bears Ears. These towns included Moab, Monticello, and Blanding, Utah. From the VIIRS data, we identified and located 24 sites to collect field nighttime light emissions using a Sky Quality light meter. In-field light measurements were compared to Visible Infrared Radiometer Suite (VIIRS) measurements. We attempt to understand how land development of nearby border towns may influence the future impact of light pollution using historical aerial imagery, VIIRS data (2012 and 2023), and visitation numbers from nearby Arches National Park. Historical aerial images from the 1950s and 2024 were digitized and compared using ArcGIS Pro. Maps were created to compare VIIRS light readings from 2012 and 2024. The data shows significant growth in development in all three towns, and expansion of light from 2012 to 2023 and demonstrates the large role oil and gas play in light pollution readings. We were able to identify areas of high light pollution and places at risk for further light pollution.

Introduction:

Light pollution poses a significant threat to dark skies. Dark skies protection began in the early 1900s with the first Dark Sky Reserve in New Zealand. Since then, dark skies conservation has gained traction. According to darksky.org, there are 200 plus Dark Sky Places around the world in twenty two countries (International Dark-Sky Association, 2025). There are a few different distinctions including dark sky preserves, dark sky reserves, and dark sky sanctuaries. The International Dark-Sky Association utilizes the Bortle Scale, "a nine-level numeric scale that measures the night sky's brightness of a particular location" and quantifies astronomical observability of celestial objects (International Dark-Sky Association). Areas with a lower Bortle Scale number have higher observability and those with a higher number have a lower observability.

Moab, Monticello, and Blanding are three towns bordering the Bears Ears National Monument area selected as study sites in Southeast Utah across Grand and San Juan County, using VIIRS (Visible Infrared Imaging Radiometer Suite) data. VIIRS data is collected by NASA to create "visible and infrared imagery along with global observations of Earth's land, atmosphere, cryosphere, and ocean" (NASA Earthdata). The area and population of each of these towns have increased since the 1950s and communities take varying approaches to dark sky conservation. The City of Moab became an

International Dark Sky Community in the last year after updating their outdoor light code. Bears Ears is considering a dark skies designation as well.

This study investigates changes in the amount of artificial light pollution in relation to the growth of these three towns and the growth of Southeast Utah over time. The purpose of this research is to determine risk of light pollution to the area by looking at current and historical data. This study compares the old historical spatial extent of town to what we see today in order to draw conclusions about the level of risk of light pollution to Bears Ears associated with development. Light pollution is tied to population growth and conversion of open lands to built environments. This study shows that more development is correlated to more light pollution. If development continues at the rate it has since 1950 and 2012, then light pollution in the area will continue to expand and may affect the visibility of stars in the area. This is a topic of concern for residents and the tribes that co-manage Bears Ears as they consider a dark skies designation.

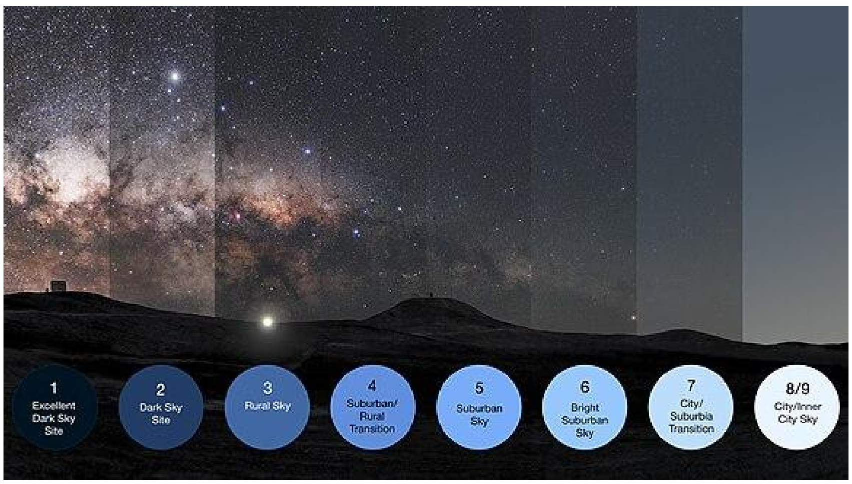


Figure 1. Bortle Scale showing effects of light pollution (European Southern Observatory).

Methods:

ArcGIS Pro/Site Selection

Using ArcGIS Pro, VIIRS (Visible Infrared Imaging Radiometer Suite) data was layered onto a ArcGIS Pro base map. Data was then clipped to two counties—Grand and San Juan County, both in Southeast Utah bordering Bears Ears National Monument. From there, symbology was used to classify the data with Natural Breaks (Jenks) of 20 classes to visually display the data. Each county then had an identifiable range of high and low values. Within the two counties, we identified twenty-four locations to collect on-the-ground data. Sites were selected on a range from highest to lowest VIIRS readings. Within that range there were spikes that seemed inconsistent with the light radiating from the center of town, so those were added. Each site was categorized as in the town proper or areas outside the town boundary. We located and sampled nine sites in Blanding; three outside of town near Montezuma Creek, and six sites inside the town. We located and sampled seven sites in Monticello; all relatively close to town. In Moab we located and sampled eight sites total with four outside town and four near town. One location was significantly further south of the town boundary. The coordinates of these sites were then added to the map using the raster to point tool in ArcGIS Pro. This gave each pixel with a light reading a coordinate to match. These coordinates were then exported to the field maps application, then located in the field.

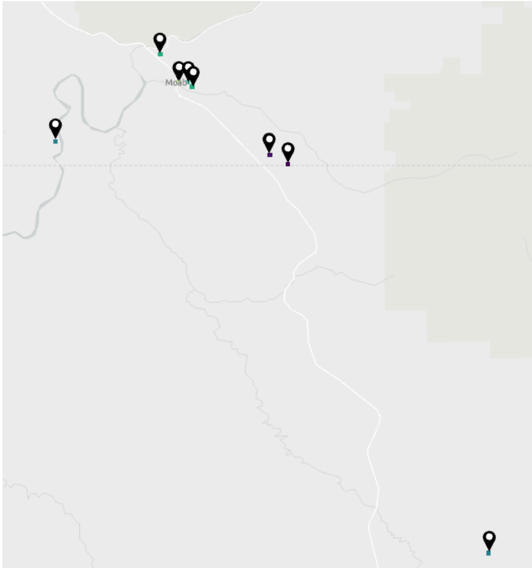


Figure 2. Moab ground data collection sites.

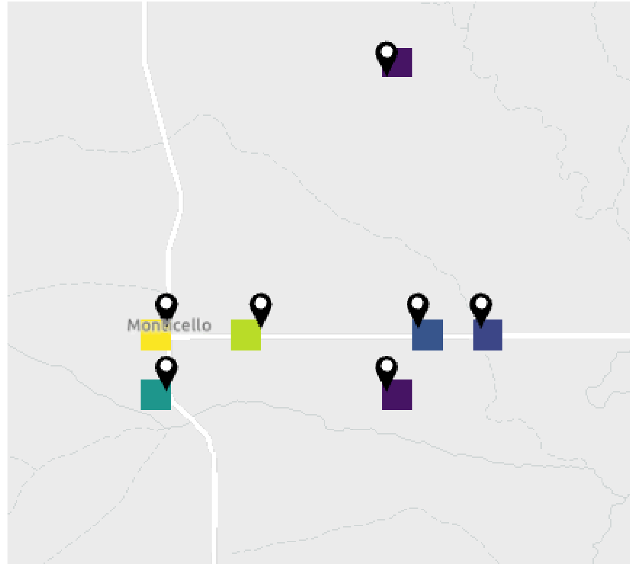


Figure 3. Monticello ground data collection sites.

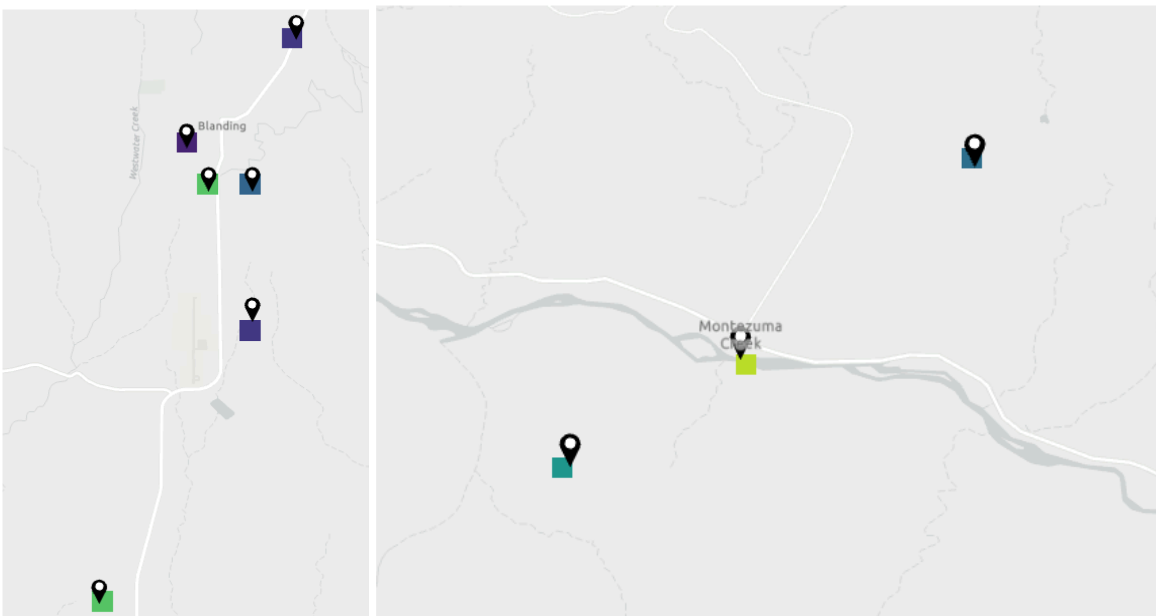


Figure 4.1 and 4.2. Blanding and Montezuma Creek ground data collection sites.

<u>Data Collection</u>

We drove to each of the selected sites using GIS to scout the surroundings and photograph during the day. After sundown, we drove out to the sites again. We identified each site using the landmark we identified earlier that day. Some locations were defined by a strong light source and so were named after that. Other sites are identified by the name of the road nearby. We waited until dark and the stars were visible (if the sky was clear that night) to start taking light measurements. An R-07 made by Roland was used to collect 10-minute sound recordings at each site. For each town, a high and low decibel reading was identified. A Sky Quality Meter was used to collect light data and using a compass, we identified all four cardinal directions and took a light reading from approximately a 90 degree angle upward in each direction. The light meter gave us readings between 17 and 23 mags/arcsec^2. While these measurements were being taken, 10-minute sound recordings were also collected. Darker locations were characterized by loud cricket sounds, power plants often had a low hum, and locations next to a road were typically quiet with the exceptions of cars passing by.

Lower numbers indicated higher levels of light pollution and higher numbers indicated lower levels of light pollution. All four readings were recorded on paper and then the sound recording was taken. Photographs were also taken at each location using a long exposure and sometimes a fisheye lens depending on light level. We then drove to the next site. Over the course of four trips, data was collected at all 24 locations. During this time, profile interviews were also conducted. The recorded light data was then uploaded into ArcGIS Pro where it could be visually compared to the pre-existing VIIRS readings.

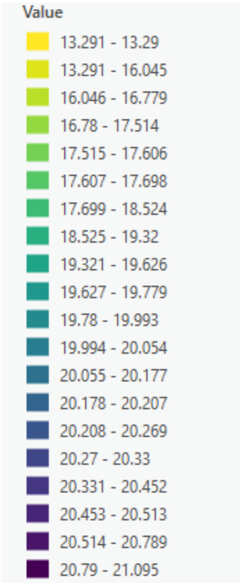
Image 1. Intrepid Potash during the night. Moab, Utah.

Image 2. Intrepid Potash during the day. Moab, Utah.

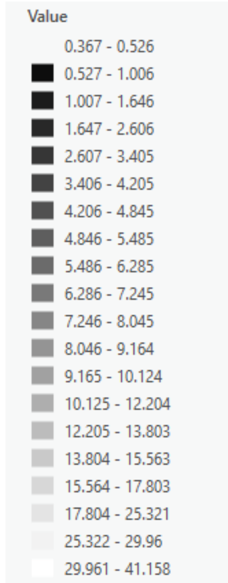
Image 3. Truckstop during the night. Monticello, Utah.

Image 4. Truckstop during the day. Monticello, Utah.

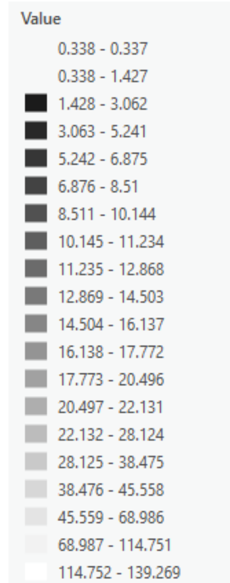
Light Meter Key:



Grand County Key:



San Juan Count Key:



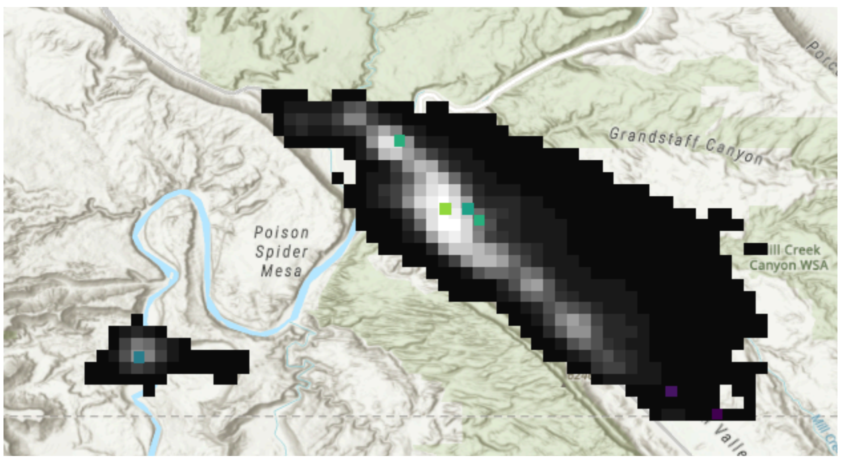


Figure 5. VIIRS light data overlaid with collected ground light meter data in Moab, UT (2024).

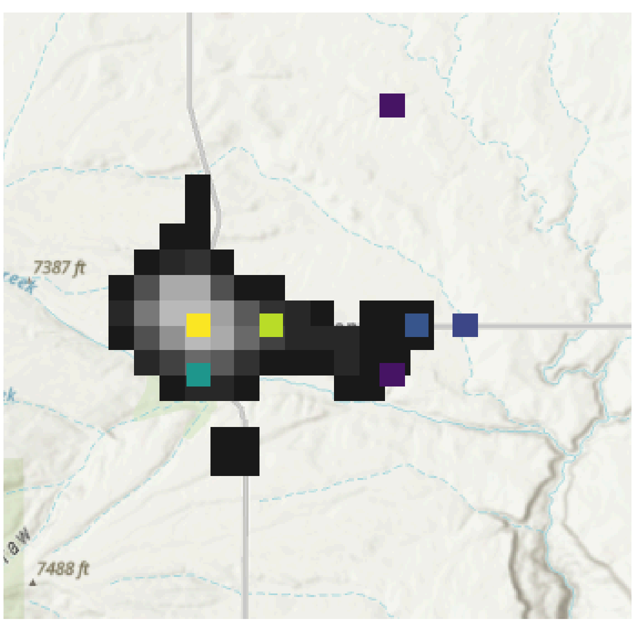


Figure 6. VIIRS light data overlaid with collected ground light meter data in Monticello, UT (2024).

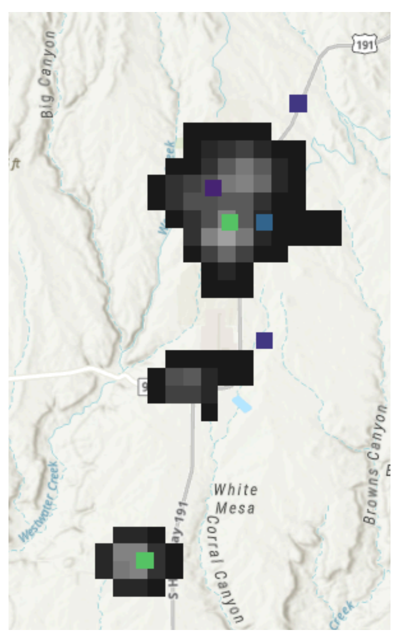


Figure 7. VIIRS data overlaid with collected ground light meter data Blanding, UT (2024).

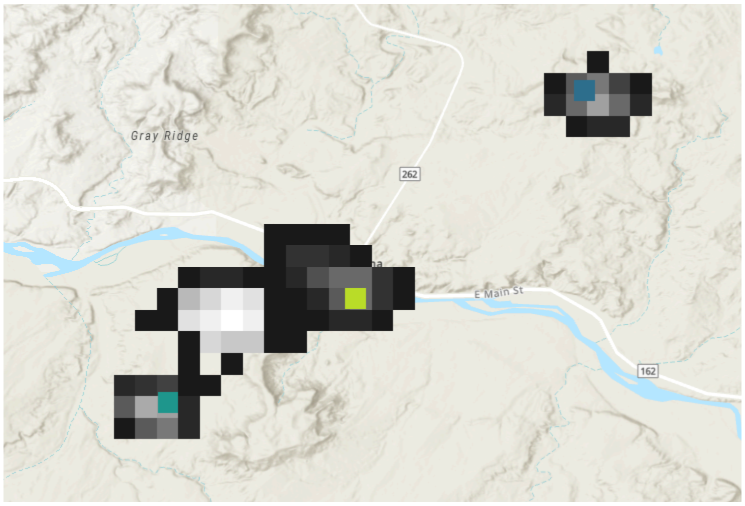


Figure 8. VIIRS light data overlaid with collected ground light meter data in Montezuma Creek, UT.

<u>Sound Data:</u>

Town High/Low	Location	Decibel Reading	Recording Number
Blanding High	Kiva Drive	-14.96	0.0024
Blanding Low	400th S	-43.34	0.0023
Monticello High	N. Long Draw	-13.63	0.0027
Monticello Low	RV Park	-37.14	0.0029
Moab High	Intrepid Potash	-18.51	0.0039
Moab Low	Spanish Valley	-43.81	0.0036

Table. 1. High and low decibel readings for each town where light data was collected (corresponds to the audacity images below).

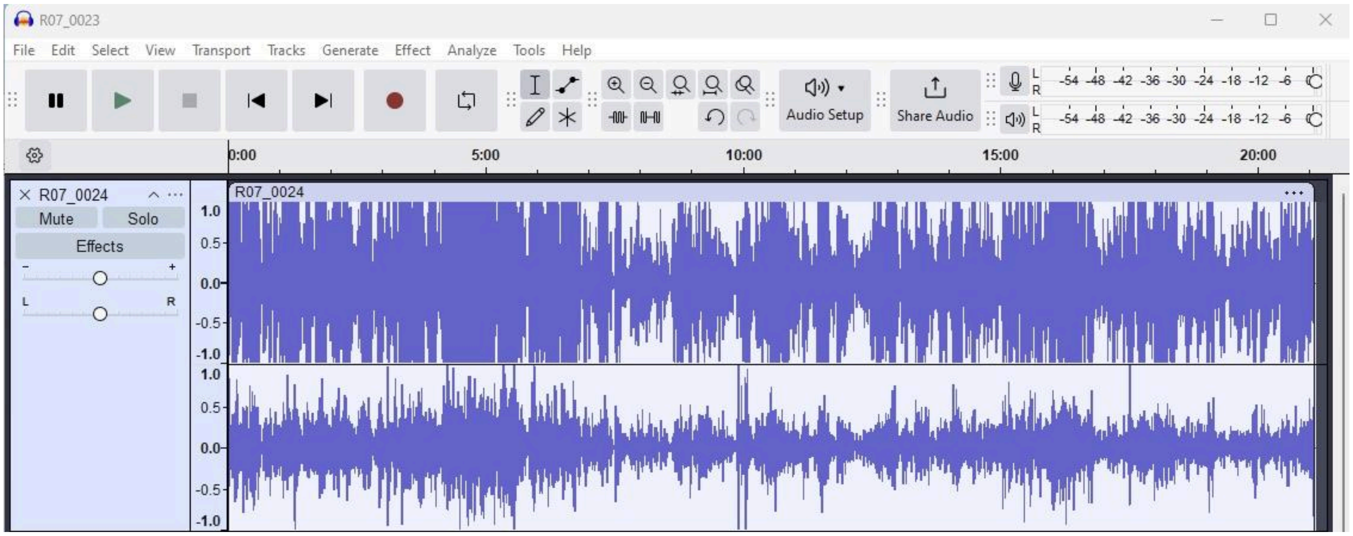


Figure 9.1. Highest decibel reading from Blanding area.

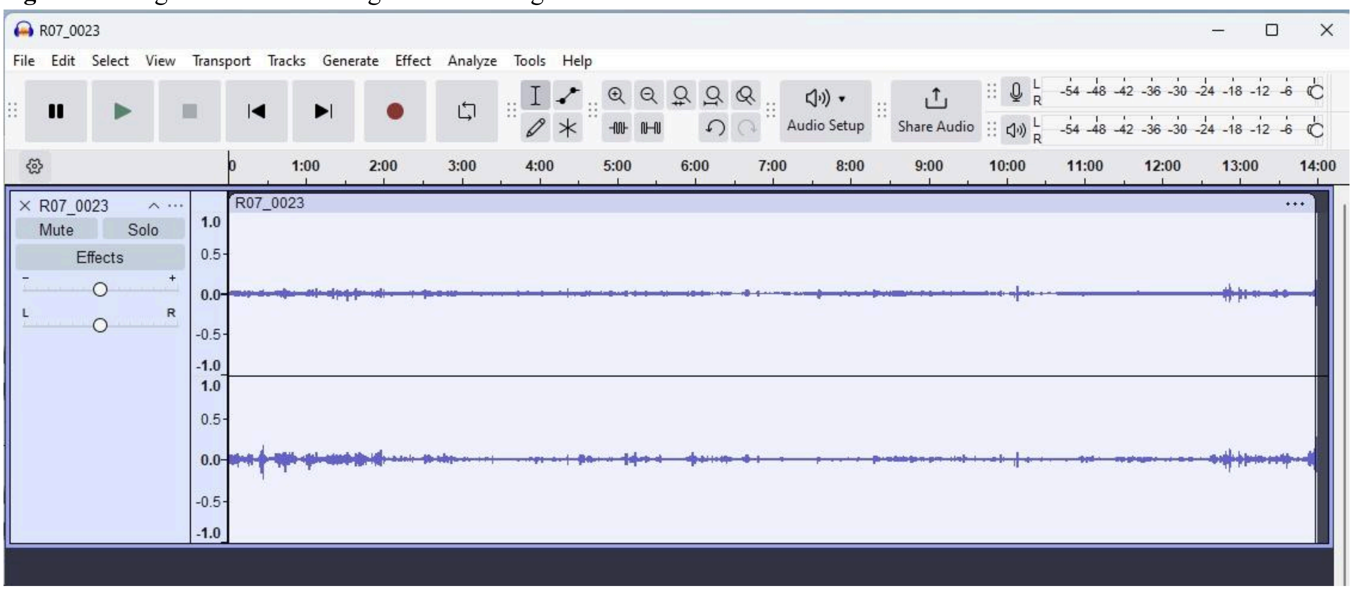


Figure 9.2. Lowest decibel reading from Blanding area.

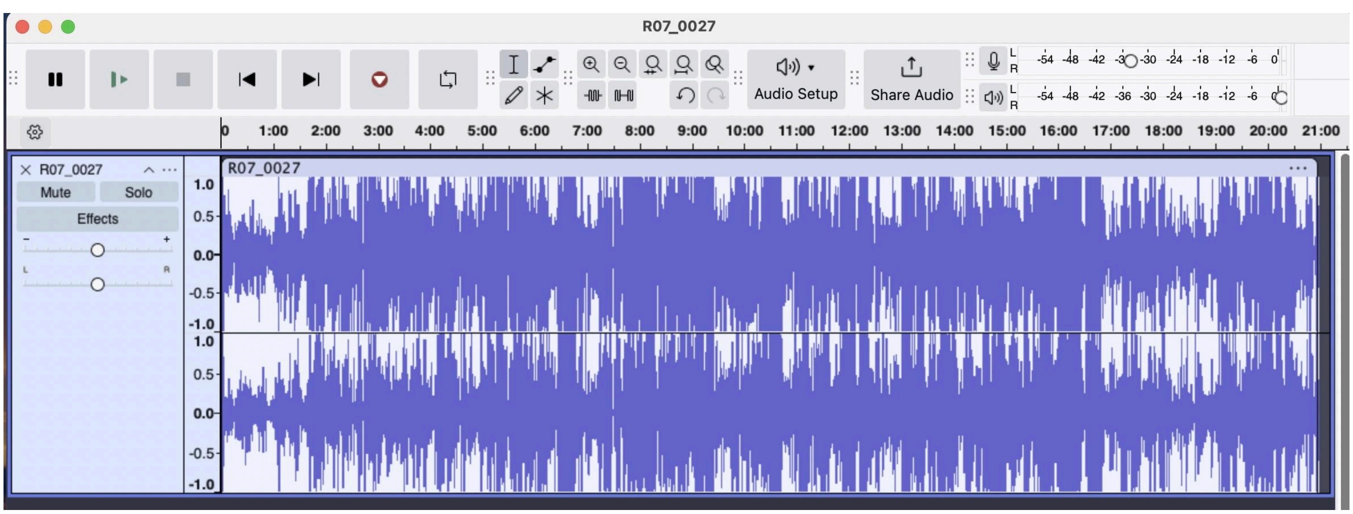


Figure 10.1. Highest decibel reading from Monticello area.

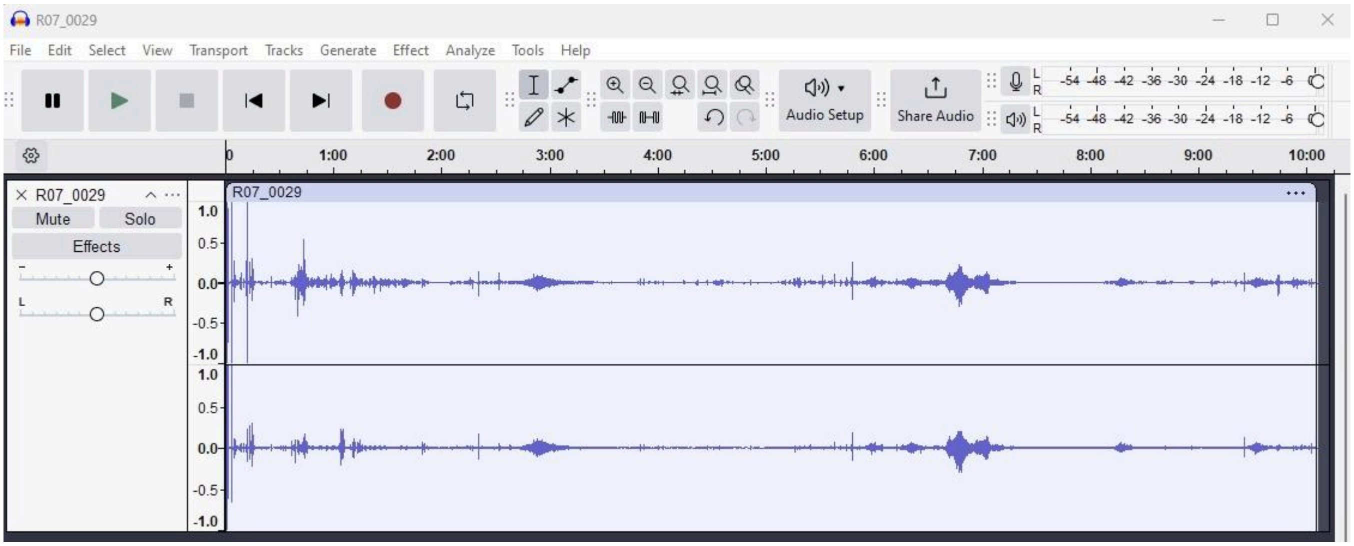


Figure 10.2. Lowest decibel reading from Monticello area.

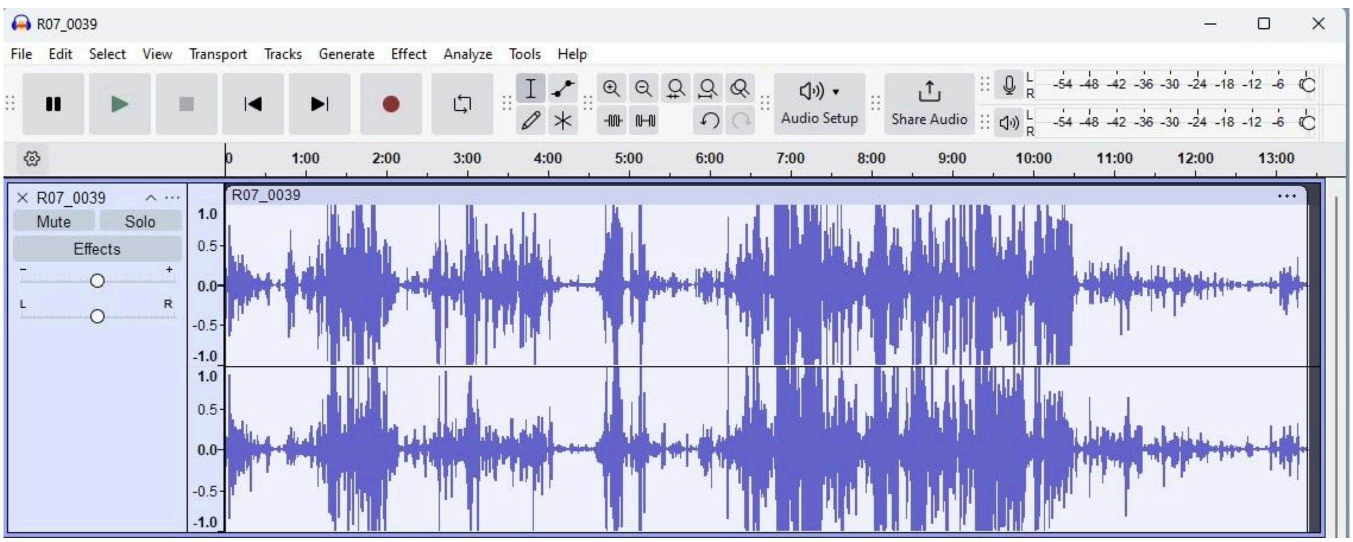


Figure 11.1. Highest decibel reading from Moab area.

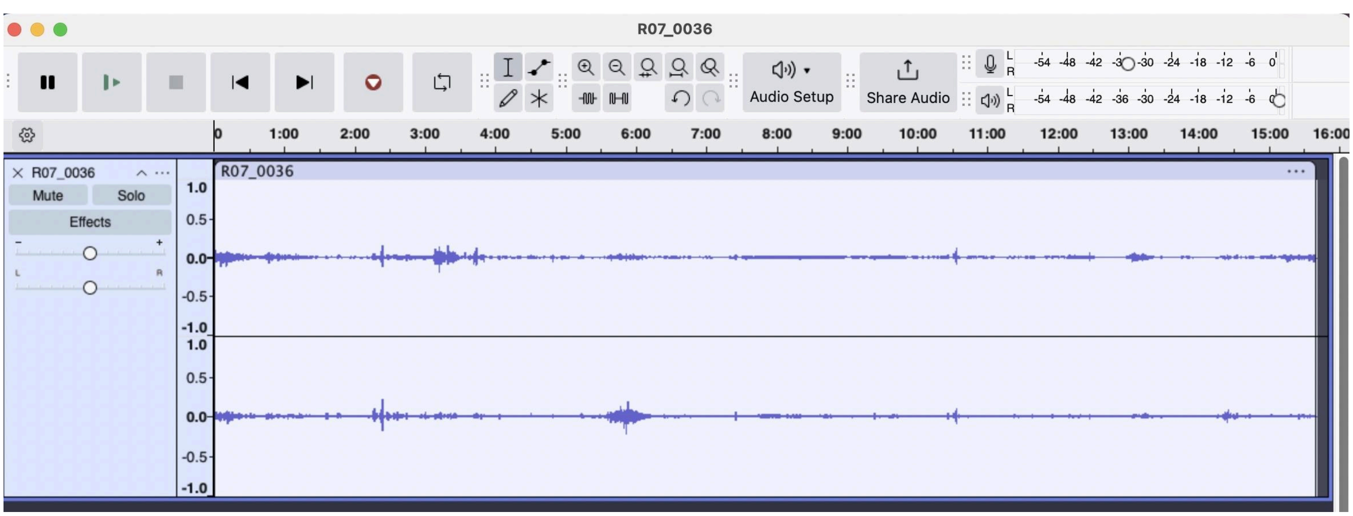


Figure 11.2. Lowest decibel reading from Moab area.

Town	Location	Decibel Readings	Recording #
Blanding	Montezuma Elementary	-29.94	0.0012
Blanding	N Montezuma Elk Petrol	-34.63	0.0014
Blanding	The Field	-31.64	0.0015
Blanding	Clarks Market	-27.62	0.0016
Blanding	Energy Fuels Uranium	-25.76	0.0019
Blanding	Eagle View Lane	-26.39	0.0021
Blanding	400th S	-43.34	0.0023
Blanding	Kiva Drive	-14.96	0.0024
Monticello	N Long Draw	-13.63	0.0027
Monticello	Exxon Station	-17.63	0.0028
Monticello	RV Park	-37.14	0.0029
Monticello	Dept Transportation	-19.75	0.003
Monticello	Bronson Road	-32.63	0.0031
Monticello	Port of Entry	-22.14	0.0033
Monticello	Power Plant	-15.57	0.0034
Moab	Lisbon Paradox	-24.36	0.0035
Moab	Spanish Valley Houses	-43.81	0.0036
Moab	Spanish Valley Overlook	-18.9	0.0037
Moab	Sheriffs Dept	-22.51	0.0038
Moab	Intrepid Potash	-18.51	0.0039
Moab	E Center	-42.6	0.0041
Moab	Redrock	-42.17	0.0043
Moab	Lions Club Park	-22.61	0.0044

Table 2. All sound recordings for each location where light data was collected on the ground with the highest and lowest decibel readings highlighted to correspond to audacity images.

Aerial Imagery/ArcGIS Pro

Using ArcGIS Pro, historical land cover was also compared to modern day land cover of Moab, Monticello, and Blanding. Historical aerial imagery was obtained from the Utah Geological Survey's Aerial Imagery Database. One image was selected from the early 1950s for both Blanding and Monticello. For Moab, eight images were used and and overlaid on top of eachother. Then, each image was georeferenced to the basemap. After each image lined up appropriately, digitizing began. Categories (5) were identified: Water Features (blue), Developed Land (red), Roads (black), Open Space (yellow), and Agriculture (green). Using shape files for each category for both 1950 and 2023, land cover was identified and digitized for all areas included in the historical imagery. The total area per land cover class was calculated. The land cover change was compared over time and across categories.

Moab

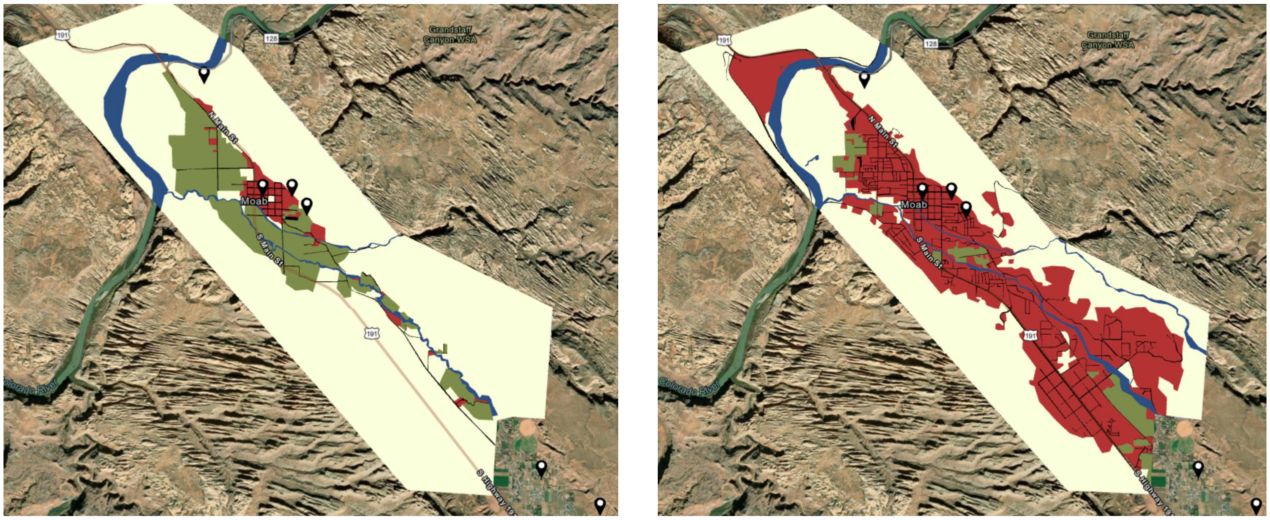


Figure 12.1 and 12.2. Digitized spatio-temporal changes in land cover categories (1950 to 2024) in Moab, UT.

Land Cover Type	1950 (m^2)	2024 (m^2)	Percent Change %
Developed Land	1,290,145	20,002,281	1450%
Agriculture	7,454,785	1,989,991	-73%
Open Space	50,720,432	35,004,311	-31%
Roads	1,183,608	2,434,266	106%
Water Features	2,582,088	4,181,847	62%

Table 3. Percent of land cover changes of 5 categories (1950 to 2024) in Moab, UT.

Monticello

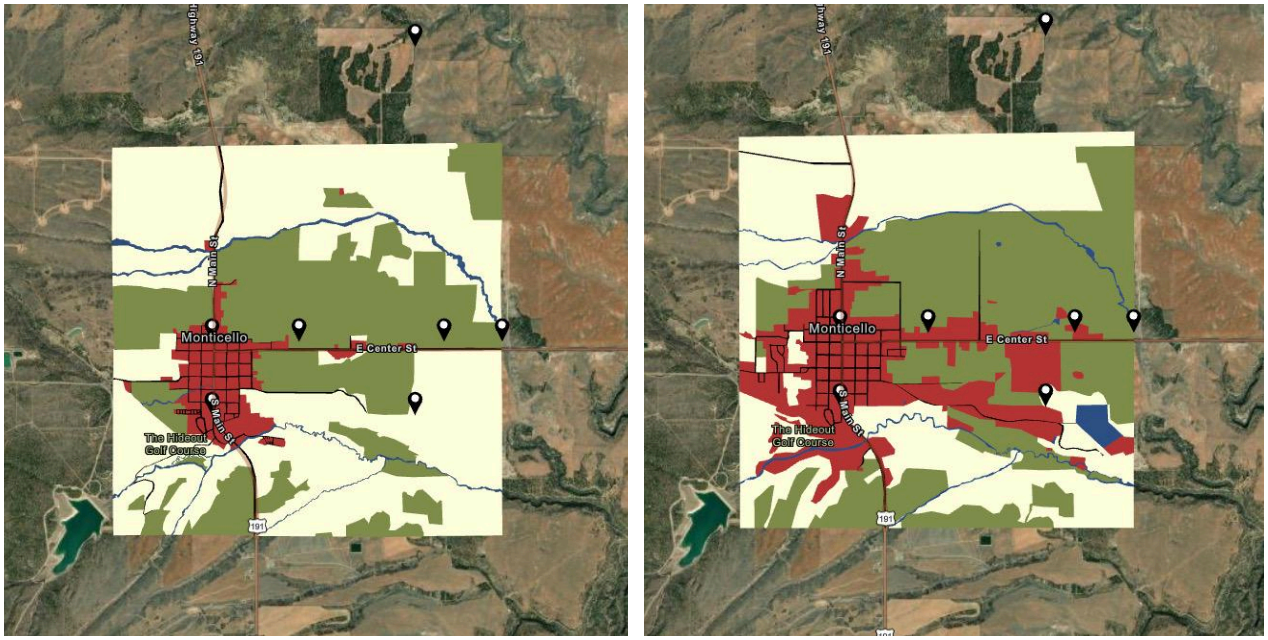


Figure 13.1 and 13.2. Digitized spatio-temporal changes in land cover categories (1950 to 2024) in Monticello, UT.

Land Cover Type	1950 (m^2)	2024 (m^2)	Percent Change %
Developed Land	1,371,779	4,577,462	234%
Agriculture	8,206,593	9,435,847	15%
Open Space	13,741,916	9,461,066	-31%
Roads	432,572	551,479	28%
Water Features	386,366	520,053	35%

Table 4. Percent of land cover changes of 5 categories (1950 to 2024) in Monticello, UT.

Blanding

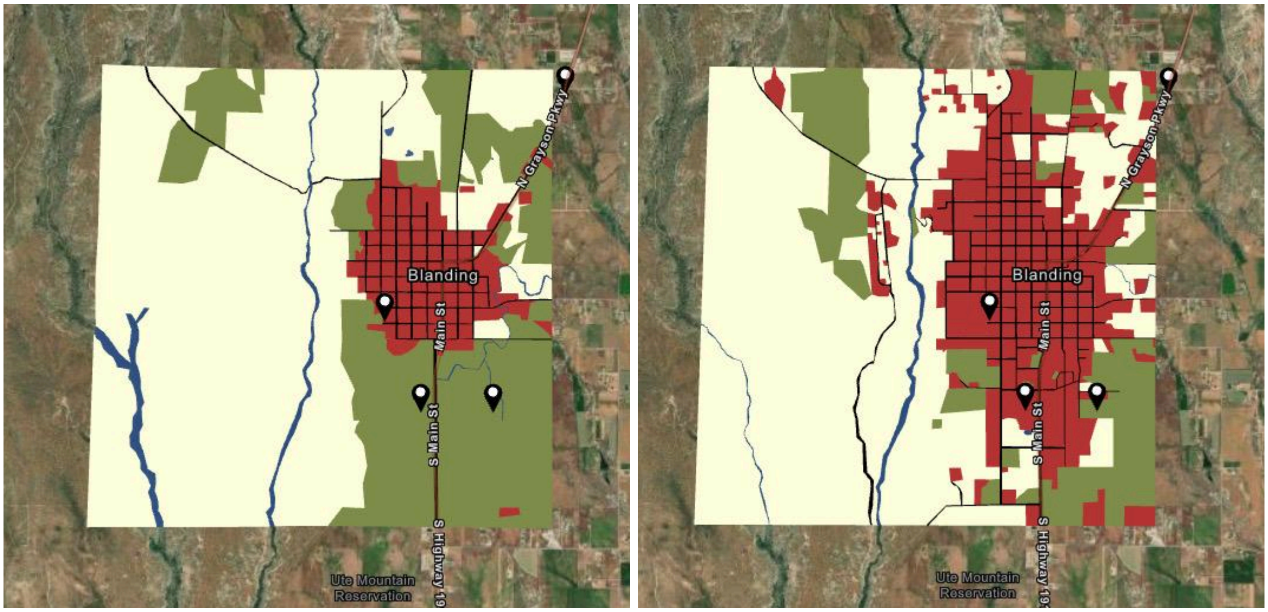


Figure 14.1 and 14.2. Digitized spatio-temporal changes in land cover categories (1950 to 2024) in Blanding, UT.

Land Cover Type	1950 (m^2)	2024 (m^2)	Percent Change %
Developed Land	1,800,885	5,115,396	184%
Agriculture	6,338,901	3,389,566	-47%
Open Space	12,937,166	12,278,345	-5%
Roads	534,176	916,005	72%
Water Features	440,853	254,206	-42%

Table 5. Percent of land cover changes of 5 categories (1950 to 2024) in Blanding, UT.

<u>VIIRS Change Over Time</u>:

To determine light change over time, the VIIRS data was examined to identify the earliest available readings, which dated back to 2012. This data was uploaded to the map and clipped to each county, as previously mentioned. The same process was repeated for 2023. The data was then classified into 20 categories. This classification ensured that each category, represented by a specific color, maintained a consistent range of values across time and locations. Percent change was calculated by identifying the unique values of each pixel where data was collected. The coordinate table was converted to points and uploaded to the map, with each point corresponding to a pixel containing a specific light reading. Light readings from both 2012 and 2023 were collected, and percent change was calculated. Additionally, changes in visitation numbers at Arches National Park near Moab, UT, were analyzed.

Location	2012 Reading (w/m²·sr)	2023 Reading (w/m²·sr)	Percent Change
Elk Oil and Gas	1.31	22.12	1588.55%
Montezuma Elementary	4.90	10.66	117.55%
Elk Petrol N. Montezuma	16.60	18.11	9.10%
The Field	0.06	0.52	766.67%
Energy Fuels Uranium Mining	10.28	15.21	47.96%
Clark's Market	5.66	20.43	260.95%
Eagle View Lane	0.87	4.51	418.39%
400th South Street	6.17	9.56	54.94%
Kiva Drive	0.23	1.00	334.78%
N Long Draw	0.05	0.42	740.00%
Exxon Station	13.11	28.11	114.42%
RV Park	9.78	12.64	29.24%
Dept Transportation	2.22	6.36	186.49%
Bronson Rd	0.13	2.02	1453.85%
Port of Entry	0.23	1.59	591.30%
Distribution Substation	0.25	3.01	1104.00%
Lisbon Paradox	24.80	45.87	84.96%
Spanish Valley House	0.37	0.94	154.05%
Spanish Valley Overlook	0.14	0.62	342.86%
Intrepid Potash	4.37	8.80	101.37%
Sheriffs Dept	17.89	41.16	130.07%
E Center St	4.46	13.88	211.21%
Red Rock/Mormon Church	2.74	6.90	151.82%
Lions Club Park	4.76	20.51	330.88%

Table 6. Comparison of VIIRS reading percent change from 2012 to 2023. Each location is one where I collected my own reading and has an associated pixel in arcGISpro. I took the reading at that pixel from the 2012 annual average and the 2023 annual average and then calculated percent change to determine how much light had increased at each location over time.

Map Key:

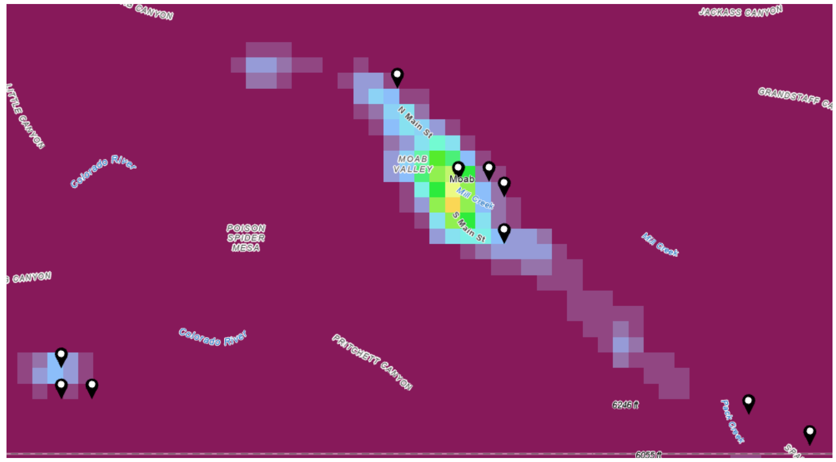


Figure 15. Moab VIIRS light readings 2012.

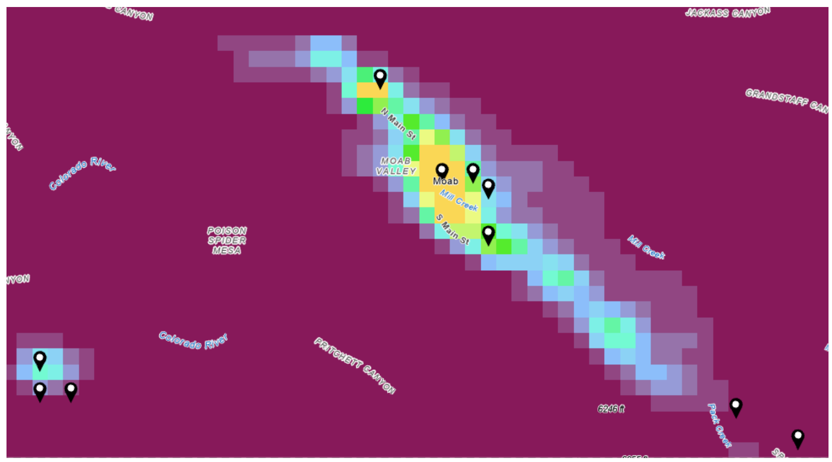


Figure 16. Moab VIIRS light readings 2023.

Map Key:

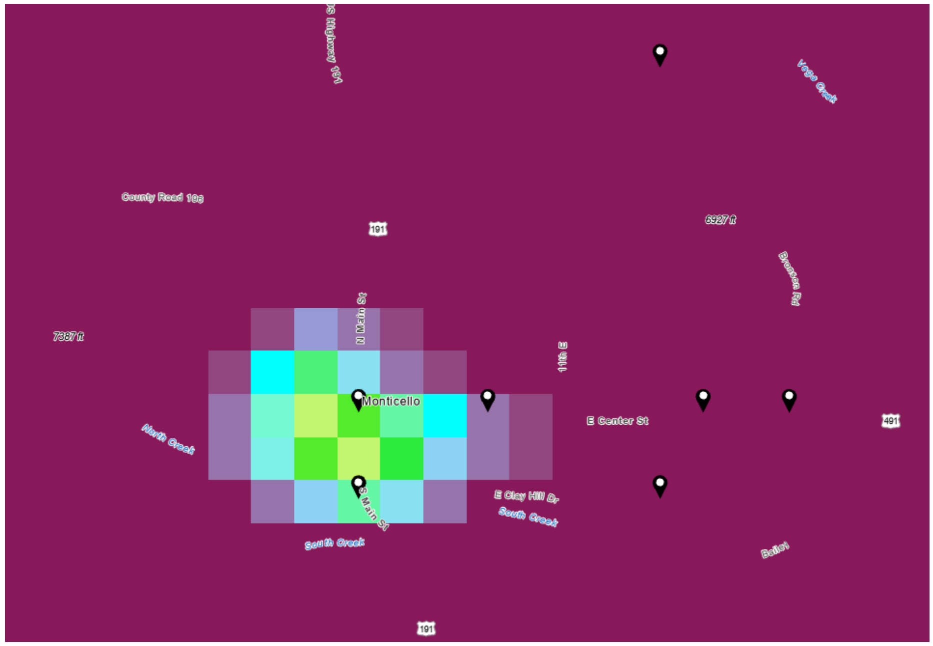


Figure 17. Monticello VIIRS light reading 2012.

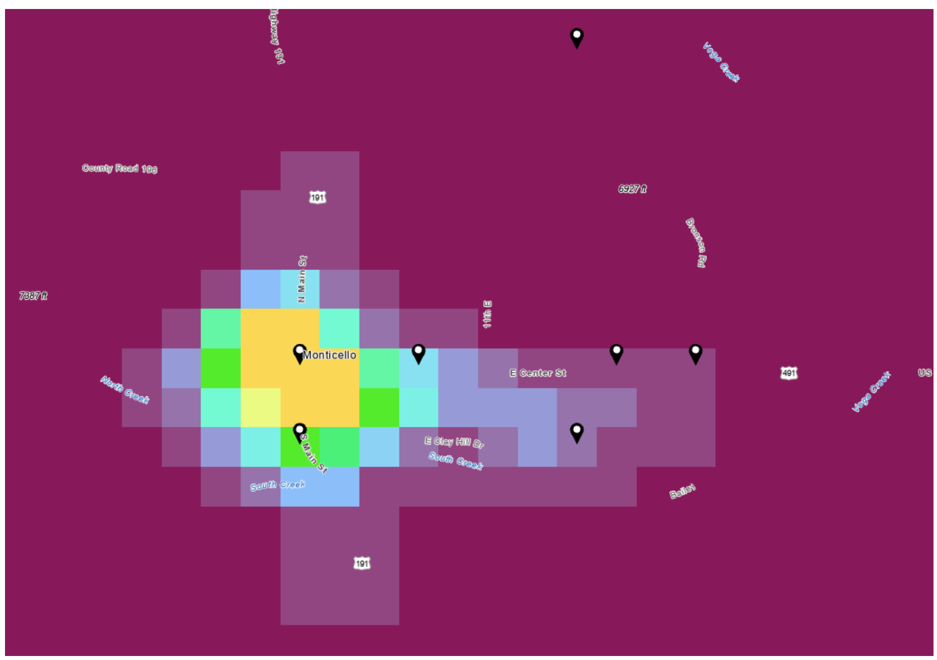
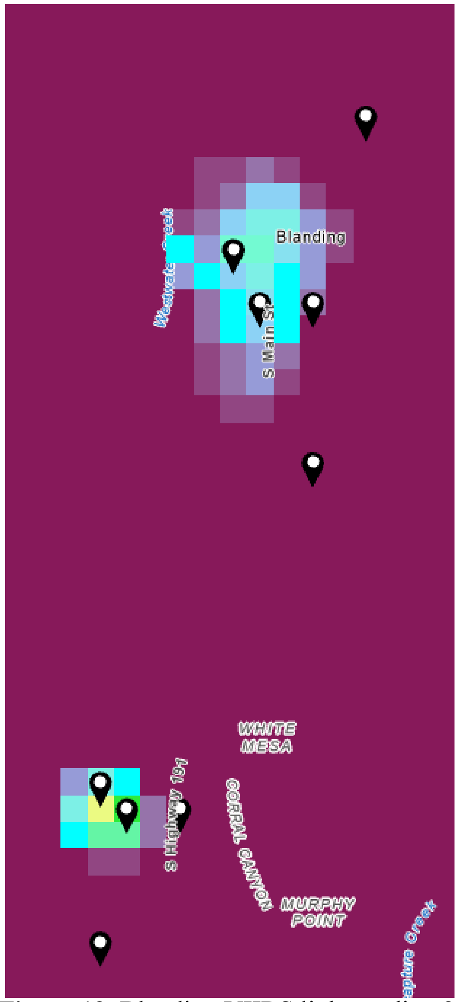


Figure 18. Monticello VIIRS light reading 2023.

Map Key:



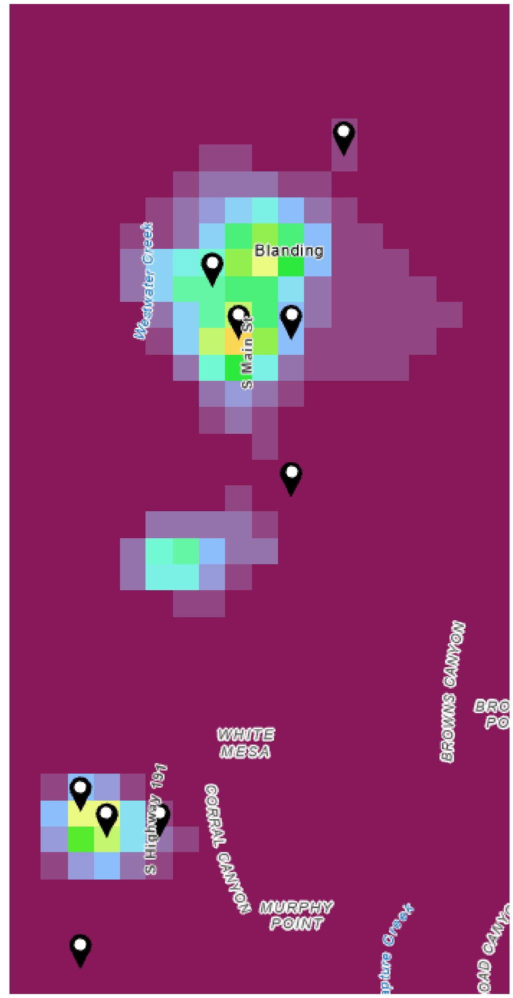


Figure 19. Blanding VIIRS light reading 2012. **Figure 20.** Blanding VIIRS light reading 2023.

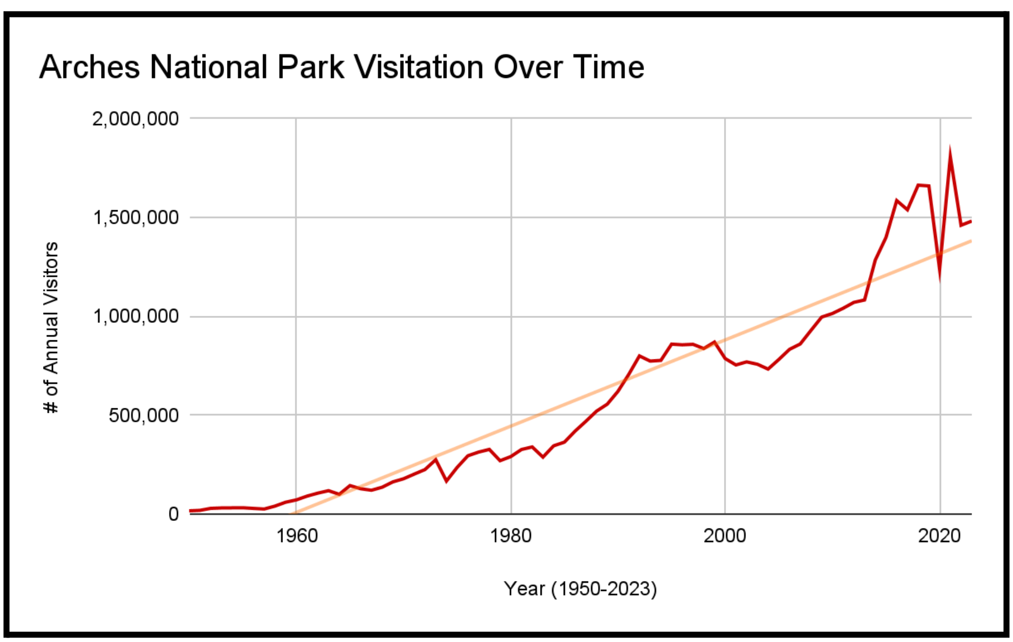


Fig. 21. Arches National Park visitation over time demonstrates a consistent increase in the number of visitors from 1950 to present day. The time frame here is consistent with the land cover maps seen in **Figures 12.1** and **12.2** and **Table 3** (nps).

Town	Population 1950	Population 2024	Percent Change
Moab	1,274	5,221	309.91%
Monticello	1,172	1,729	32.22%
Blanding	1,177	3,189	170.94%

Table 7. Population growth of each town comparing 1950 to 2023 (World Population Review).

Results:

Developed land increased from the 1950s to 2024 in all three towns. From 2012 to 2024, light pollution levels rose in all three towns. The data collection and findings demonstrate an increase in light pollution over time in the area surrounding Bears Ears National Monument and a transition in the types of land cover categories that are prevalent in Moab, Monticello, and Blanding. Both show change in the area because of development. The increase of both light and development suggests a correlation between development and increased levels of light. The data collected shows consistency with VIIRS imagery, demonstrating the accuracy of VIIRS readings with one notable exception: oil and gas plants. The highest VIIRS readings were from locations of oil and gas flaring, but the brightest Sky Quality Meter readings came from the center of the three towns. Those areas with the white pixels overlapped with my brightest readings at each location. Montezuma Creek (with multiple oil and gas rigs) was the notable exception. These findings demonstrate a risk of light pollution to the Bears Ears National Monument Area if development and light trends continue.

By looking at visitation numbers from Arches National Park from 1950 to present day, we can see an increase in the numbers of visitors over time. This seems to correlate to the development trends in Moab from 1950 to 2024 which we can see in **Figures 12.1** and **12.2** and **Table 3.** The increase in visitation requires more development and infrastructure to support the people coming to the Arches area. Moab and Arches is a case study that can theoretically be applied to Bears Ears National Monument and the towns that surround it.

The findings from this research demonstrate an increase in light pollution over time in the area surrounding Bears Ears National Monument and a transition in the types of land cover categories that are prevalent in Moab, Monticello, and Blanding. Both of these things show change in the area as a result of development. The increase of both light and development suggests a correlation between development and increased levels of light. We can also see consistency with VIIRS imagery, demonstrating the accuracy of VIIRS readings with one notable exception: oil and gas plants. The highest VIIRS readings were from locations of oil and gas flaring, but the brightest Sky Quality Meter readings came from the center of the three towns. Generally speaking, those areas with the white pixels overlapped with my brightest readings at each location. Montezuma Creek (with multiple oil and gas rigs) was the notable exception.

Image 5. Flare from oil and gas rig in Southeast Utah.

In terms of increased light pollution, there was a positive percent change in light pollution from VIIRS data ($w/m^2 \cdot sr$) at all 24 locations across Southeast Utah from 2012 to 2023 (**Table 6**). Each town center fits under the 17th range, color orange (**Fig. 15** through **Fig. 20)**. The area that the light reached (anything not in the first range, maroon color) increased in each location. In addition to light increase, Arches National Park saw a consistent increase in visitation with a notable dip in 2020 most likely correlating to the COVID-19 global pandemic. The overall trendline shows a linear increase in visitation.

To draw conclusions over a longer time period, we examined five land cover types (developed land, agriculture, open space, roads, and water features) in 1950 and 2024 in Moab, Monticello, and Blanding. In Moab (**Fig. 12.1** and **12.2** and **Table 3**), developed land increased by 1450% from 1950 to 2024. Agriculture decreased by -73%. Open space decreased by -31%. Roads increased by 106%. Water features increased by 62%. This shows a boom in developed land, pushing agriculture further south and shrinking the available open space in the area.

In Monticello (**Fig. 13.1** and **13.2** and **Table 4**), developed land increased by 234%, agriculture increased by 15%, open space decreased by -31%, roads increased by 28%, and water features increased by 35%. This supports the statement that agriculture moved south, as agriculture increased. In fact the only category that decreased was open space. Monticello's highest area of increase was also developed land.

In Blanding (**Fig. 14.1** and **14.2** and **Table 5**), we can see that developed land increased by 184%, agriculture decreased by -47%, open space decreased by -5%, roads increased by 72%, and water features decreased by -42%. Again, the highest area of increase was developed land. Similarly to Moab, there was a decrease in agriculture. Open space stayed relatively consistent, where land that was once agriculture became developed.

The sound recordings provide interesting information regarding the types of auditory experiences that can exist at each location. The highest decibel reading, or loudest, across all three towns was in Monticello at North Long Draw which had an average light reading of 20.515 mags/arcsec^2. This wasn't the darkest location in Monticello, but it was also not the highest. The sound experience seems to not be tied to the amount of light. The lowest decibel reading, or quietest, was found in the Spanish Valley Housing location. The average light reading from that location was 20.655 mags/arcsec^2. This is not far off from the loudest location (**Table 1**).

Across all three towns developed land increased the most. Moab had the most dramatic change with the highest percent change in land cover of all three towns across all five categories. Roads also increased across all three towns. Open space decreased in all three towns, as well. Agriculture and water were the most inconsistent and seemed to be dependent on town.

<u>Moab Historical Photographs (Moab Museum):</u>

The historical places shown below represent what Moab looked like at and around the time the land cover categories from the 1950s were created. By looking at these images one can see the change in size and aesthetic today. The increased development is visible across these images. Moab is a good example of modernization, increase in aerial extent seen via the imagery presented previously, and population growth leading to more light pollution. The table below (**Table 7**) showcasing population change from 1950 to 2024 shows growth in the town in terms of population as well as development. The population from all three towns has increased over time, with Moab having the largest percent change. This is consistent with Moab having the biggest increase in development land as well.

Town	**Population 1950**	**Population 2024**	**Percent Change**
Moab	1,274	5,221	309.91%
Monticello	1,172	1,729	32.22%
Blanding	1,177	3,189	170.94%

Table 7. Population growth of each town comparing 1950 to 2024 (World Population Review).

Image 6. Main street of Moab, 1940s sourced from the Moab Museum.

Image 7. Main street of Moab, 2024.

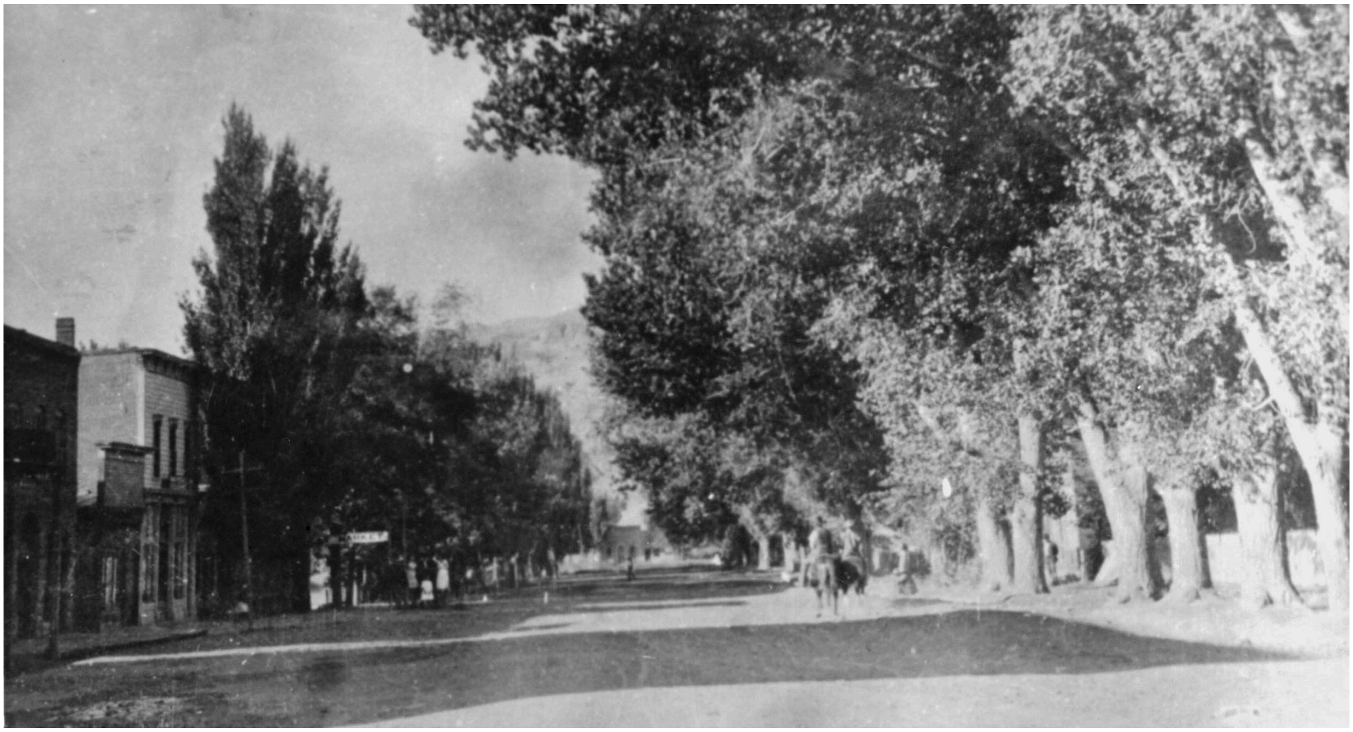


Image 8. Main street of Moab, 1920s sourced from the Moab Museum.

Image 9. Main street of Moab, 2024.

Image 10. First National Bank in Moab, 1954 sourced from the Moab Museum.

Image 11. Zions Bank Moab, 2024.

Image 12. Moab Museum, 1950s sourced from the Moab Museum.

Image 13. Moab Museum, 2024.

Discussion:

Rural development and light pollution have increased in Utah over time. As developed land has increased along with national park visitation, light readings have as well. Though there is no VIIRS light data from 1950, it is reasonable to assume that lower levels of development correspond with less light pollution. We can assume that since there was significantly less development in the area in 1950, there was also less light. One question we had at the beginning of this project was whether the on the ground light pollution experience would be different from the readings that VIIRS picked up. Generally speaking, the on the ground data matched VIIRS data though, as mentioned above, places where oil and gas flaring occurs were outliers.

The highest recorded readings by VIIRS were in locations of flaring, at times nearly doubling the readings from the center of the towns. Research shows that because of the way VIIRS collects its data it "offers a substantial advantage for the observation of gas flaring" (EOG Mines). The pixels in the VIIRS data denoting a flare, are extremely high with very few lower light pixels around it. Because of the flaring's short term nature, it was hard for us to catch a reading during a flare. In terms of risk to dark sky visibility, it is widely recognized that flaring poses less of a risk than city light pollution. This is due to the more concentrated nature of gas flaring as opposed to the more diffused and wide spread light that is emitted from street lamps and buildings. That being said, oil and gas flaring can still have negative environmental impacts, especially considering how much wildlife often inhabits more remote areas that house oil and gas plants (darksky.org)

While speaking to people in the area some expressed concern around light pollution but many did not. Interestingly, those that had moved from a larger city where they could not see as many stars expressed the most concern. Those who had lived in the Bears Ears area for their whole life, expressed the feeling that nothing had changed in their lifetime and they didn't expect anything to change in the future. Many were not able to identify the areas with the most light. All said that the stars were important to them and did not want to lose the ability to see them.

Image 14. Mary Benally at the Bears Ears Summer Gathering, one with the trees.

Conclusion:

Light pollution can affect one's ability to see stars. Many major cities around the US experience starless nights regularly. Though even the largest city near Bears Ears (Moab) only has approximately five thousand people and the largest city in the US (New York) has over eight million, light pollution still poses a risk. Light pollution in the towns surrounding Bears Ears has increased since 1950. Since 2012 the area that light pollution reaches has increased. Since 1950, there has been a significant increase in developed land and decrease in open space across Moab, Monticello, and Blanding. This information will help to guide the actions of the Inter-Tribal Coalition of Bears Ears National Monument in their decision to distinguish Bears Ears as a Dark Skies Designated Area.

Literature Cited:

International Dark-Sky Association. “International Dark Sky Places.” *DarkSky*, 2025 https://darksky.org/what-we-do/international-dark-sky-places/.

Bears Ears Inter-Tribal Coalition. “Bears Ears Inter-Tribal Coalition” *Bears Ears Coalition*, 2025 https://www.bearsearscoalition.org/.

P. Horálek, M. Wallner. “How Light Pollution Affects the Dark Night Skies.” *European Southern Observatory*, 29 June, 2022 https://commons.m.wikimedia.org/wiki/File:How_light_pollution_affects_the_dark_night_skies_(dark-skies).jpg.

National Park Service. “Annual Park Recreation Visitation (1904 - Last Calendar Year) - Arches National Park.” *Integrated Resource Management Applications (IRMA)*, 2025 https://irma.nps.gov/Stats/SSRSReports/Park%20Specific%20Reports/Annual%20Park%20Recreation%20Visitation%20(1904%20-%20Last%20Calendar%20Year)?Park=ARCH.

Earth Observation Group. “Global Gas Flaring Observed from Space.” *Colorado School of Mines*, 2021 https://eogdata.mines.edu/products/vnf/global_gas_flare.html.

World Economic Forum. “Invisible Stars: Mapping America’s Rural Light Pollution.” *World Economic Forum*, 2020, https://www.weforum.org/stories/2020/02/invisible-stars-mapping-america-s-rural-light-pollution.

World Population Review. “US Cities.” *World Population Review*, 2025 https://worldpopulationreview.com/us-cities.

International Dark-Sky Association. “Causes of Light Pollution.” *DarkSky*, 2025 https://darksky.org/resources/what-is-light-pollution/causes/.

NASA. "VIIRS." *NASA Earthdata*, 2024 https://www.earthdata.nasa.gov/data/instruments/viirs.

World Population Review. “Explore the World Population Through Data.”*World Population Review*, 2024, https://worldpopulationreview.com/.