

Participatory Mapping in Browns Canyon National Monument, Colorado (USA)

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ABSTRACT Natural resource managers need up-to-date information about how people interact with public lands and the meanings these places hold for use in planning and decision-making. This case study explains the use of public participatory Geographic Information System (GIS) to generate and analyze spatial patterns of the uses and values people hold for the Browns Canyon National Monument in Colorado. Participants drew on maps and answered questions at both live community meetings and online sessions to develop a series of maps showing detailed responses to different types of resource uses and landscape values. Results can be disaggregated by interaction types, different meaningful values, respondent characteristics, seasonality, or frequency of visit. The study was a test for the Bureau of Land Management and US Forest Service, who jointly manage the monument as they prepare their land management plan. If the information generated is as helpful throughout the entire planning process as initial responses seem, this protocol could become a component of the Bureau's planning tool kit.

KEY MESSAGE

Readers will learn the methodology of public participation GIS (PPGIS) as applied to a land management planning effort. Participatory mapping was used to generate public input about uses and perceptions of public lands. Readers will also see how results can be used and interpreted. The case study informs readers about land management planning and shows a process that could be replicated in different contexts for anybody wishing to generate information from stakeholders for resource management.

INTRODUCTION

People attach meanings to landscapes both through direct interactions and symbolic connections rendered through stories or historical accounts [1, 2]. Landscape meanings can be critical for creation of social and community identity [3]. Diverse stakeholders may attach drastically different meanings to a common space, based on the way they interact with the landscape [4]. To effectively manage public lands, federal and state resource managers need infor-

mation for two broad categories: How people use public lands (their actual interactions with the space) and their attachments to these places (the meanings these places hold). Public land agencies such as the Bureau of Land Management (BLM) and the US Forest Service (USFS) have long-proven methods to measure the biophysical attributes of place, such as soil conditions, invasive species, grazing effects, or measures of biodiversity, but often they have little data about the human interactions and emotional attachments with much of the land they administer.

Research has been ongoing for about two decades to address this lack of information. Landscape value categories, such as "economic," "aesthetic," "recreation," and "heritage" can be used to attach meaning to places on the landscape. Initial research approaches gathered public input for USFS lands where users responded to questions of landscape values by placing dots on hard copy maps using mail surveys [5]. The intent was that land managers measure the degree to which proposed activities align with the values identified by the public [6]. A variety of methods for mapping landscape values have been applied for

general land use management [5], to determine ecological hotspots and priority conservation areas [7, 8], measure social values of ecosystem services [9, 10], and find conflict resolution in land uses [11, 12], among others. With the evolution of digital mapping and the internet, these methods evolved into one facet of the growing field of Public Participation Geographic Information Systems (PPGIS). PPGIS refers to the methods for generating spatial information from the public in varying ways, and many degrees of participation, using geospatial technologies with the goal of improving the quality of land use decisions [13, 14]. Projects strive to include those traditionally excluded from the planning process—to democratize planning—by undertaking research methods that extend access to disenfranchised groups [15, 16].

Federal land management agencies in the US must develop management plans for the lands they administer [17, 18]. Early studies explored the use of PPGIS for forest planning using a survey-based landscape values approach [6, 19–21]. More recently, the diverse PPGIS approaches for measuring the public perceptions of place and interactions with the land fall under the public participatory mapping protocol developed at the USFS Pacific Northwest Research Station and Portland State University to incorporate direct public engagement and participatory mapping for use in public lands planning [22]. The approach has been referred to as Human Ecology Mapping (HEM) when used by the study team with federal land management agencies. The intent is to capture the complex interactions that characterize socioecological systems to inform land management decisions. Like other forms of PPGIS, HEM encourages citizens, stakeholders, and visitors to use maps as a means to identify values, benefits, or activities attached to particular places on the landscape. The data generated allow public land managers to see where different interactions concentrate and visualize spatial perceptions of the landscape, all for decision support to implement appropriate management plans. HEM has been applied to measure landscape values on the Olympic Peninsula of Washington [23–25], to determine a sustainable road system in the Mt. Baker-Snoqualmie National Forest in Washington [26], and currently to gather public input for future planning in the Deschutes and Ochoco National Forests in central Oregon.

Brown and Reed make several recommendations based on lessons learned when using PPGIS for national forest planning [6]. One was to start the PPGIS data collection as early as feasible in the planning process, and a second was to do so

with the explicit sanctioning and support of the federal agencies involved. It was suggested that these steps could increase participation and better inform the planners throughout the entire process. Third, the authors recommended data collections from multiple stakeholder groups using complementary methods. Finally, they discussed the benefits and drawbacks to drawing polygons or simply placing dots to identify places of interest. Dots usually are meant to represent areas, but how large of an area is unknown, so spatially aggregating the points into a density surface is the method to overcome this gap. On the other hand, polygons can be more precise, but users often draw shapes with a high degree of variability, casting doubt on the accuracy of their areas. The implied outcome of their discussion is that both methods should be used as complementary representations of user responses. We intentionally incorporated these recommendations into our research protocol.

Participatory mapping is a tool to gather public input prior to the formal planning process. This project for the Browns Canyon National Monument, Colorado, is a demonstration of the protocol, yet it differs from previous projects in several ways: (1) while the USFS has explored the use of participatory mapping at several sites, the BLM has not. Both agencies operate under different, though similar, rules, but the BLM had not worked with a research center to develop the participatory mapping procedure. This project was a test for the BLM to determine the value of participatory mapping for lands under their jurisdiction. (2) The Browns Canyon National Monument is small compared to other land management projects that used participatory mapping. This project helped determine whether the process was scalable to a much more focused setting. (3) We ran a fully integrated web-enabled mapping interface to complement live community workshops. This enabled input from two different user groups, diversifying and increasing user input. (4) Finally, this project is based on the place and not theme driven (e.g., mapping ecosystem services or motorized traffic management) but rather intended to provide meaningful data for land managers to use in the planning phase. Such an approach is crucial because Browns Canyon National Monument is jointly administered between the BLM and USFS, also with the Arkansas Headwaters run by the Colorado Parks and Wildlife who have their own Arkansas River Recreation Management Plan. Coordinating shared data among these agencies is mandatory for the site, and HEM provided a way to achieve this. The project brings new knowledge about institutional collaborative methods to the planning process.

CASE EXAMINATION

On February 19, 2015, President Barack Obama proclaimed the Browns Canyon National Monument (BCNM) under the Antiquities Act of 1906 in order to protect diverse geologic, ecological, and cultural resources, objects, and values in a rugged area of 8,700 hectares in Chaffee County, Colorado (Figure 1). The Arkansas River runs through the western edge of the monument, between the towns of Buena Vista and Salida, and is the most heavily used whitewater rafting corridor in the country. The creation of a new national monument was not without controversy and the participatory mapping workshops were viewed as a means both to expand trust and allow voices to be heard about the places and activities that matter to people. We gathered data from stakeholders and the general public in a joint BLM and USFS research framework to inform a planning assessment. The goals of this project are to foster federal–state–public relationships, build trust, and consult, identify, and compile relevant public views concerning environmental, social, and economic conditions of the BCNM. Participatory mapping was undertaken in tandem with a complementary situation assessment protocol where strategic stakeholders in the region were interviewed about their connection to the monument. While the final report includes interview responses from these stakeholders, this case study focuses only on the participatory mapping component [27].

Six workshops, or listening sessions, were held in October and November 2016 in Denver, Colorado Springs, Leadville, Buena Vista, Salida, and Cañon City, Colorado. An online web interface was developed by TierraPlan, LLC, and open to the public from October 2016 through January 2017. We recorded 311 total responses, 133 from participants at the community listening sessions and 178 from the online listening sessions. At the live sessions, up to eight participants sat at tables, along with a volunteer facilitator and note taker for table discussions (Figure 2). Two large color maps utilizing high-resolution ortho-photos, hillshade terrain images, and locational features were at each table. One showed the BCNM in detail, the other showed BCNM in the context of the surrounding area (Figure 3). Each person received a mapping booklet, a highlighter pen, and matching colored dot stickers. Ice-breaker activities asked participants to answer questions and participate in discussions of their connections with the monument. The participatory mapping protocol then began in earnest when participants were asked to map up to five areas in or near BCNM that they visit, use, or interact with in some way. These we called “resource interactions,” and participants drew polygons using different-colored pens on the

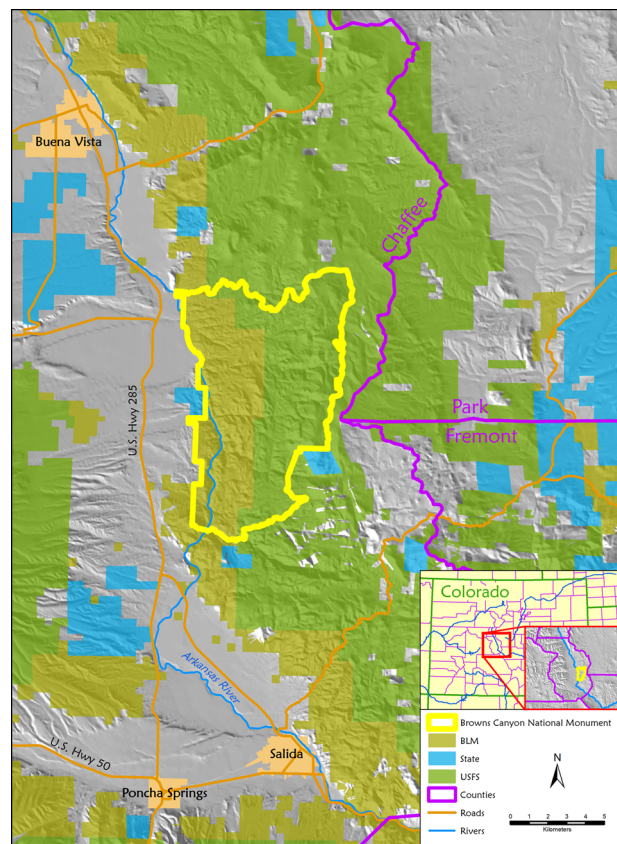


FIGURE 1. Location of the Browns Canyon National Monument.

maps, then answered questions in their mapping booklet about each place they drew (Figure 4). Each participant could map up to five different resource interaction polygons and select from a list of 39 established interaction types (grouped under six broad themes), choosing as many as applied to each area.

In the second mapping exercise, participants were asked to identify up to three places in or near BCNM that are especially significant or special to them. These “special places” differed from the resource interactions in that they are intended to be meaningful or symbolic, perhaps even places never actually visited, rather than just uses or interactions with these spaces. For the special places, participants placed colored dots on the maps rather than drawing polygons. They again answered questions in their mapping booklet regarding the name of the place, open-ended questions about the significance or meaning of the place, and the specific landscape values or benefits they assign to the place (e.g., economic, recreation, ecological, and beauty). The mapping booklet contained a list of 17 established landscape values, and participants could select all values that applied to a place (Figure 5). The participatory mapping



FIGURE 2. Resource Interaction mapping activity at Buena Vista community listening sessions. Photo by Joe Vieira.

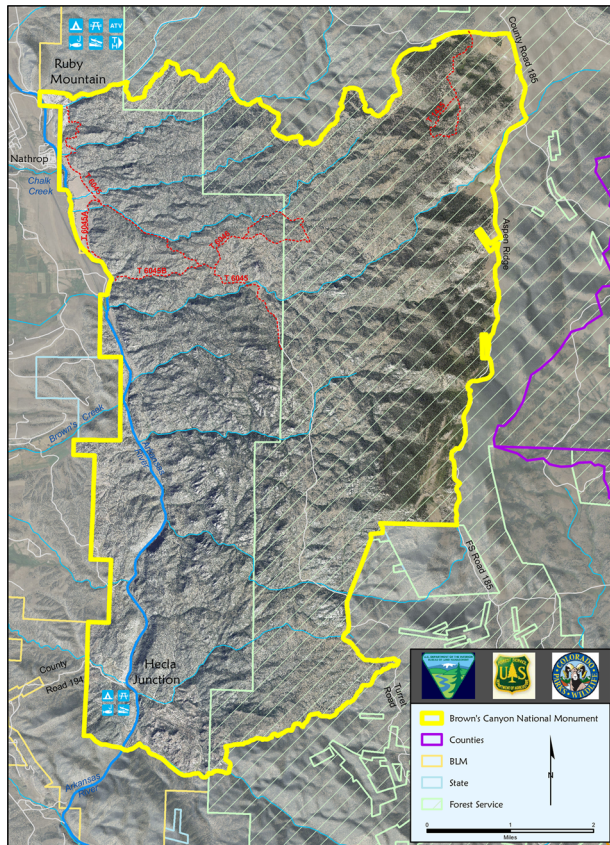


FIGURE 3. Example of map used for participants to draw their resource interactions and special places at the live listening sessions. The map sizes were 23 × 34”.

Place #1 What is this area called? _____

1.1 Seasons visited: Spring Summer Fall Winter

1.2 How often do you visit this area in a typical year? _____times/year

1.3 Interactions: What do you do in this area? Activities, hobbies, practices...
Check all that apply.

NATURE & HERITAGE ☐ View nature ☐ Photography/Art ☐ Watch wildlife ☐ Bird watching ☐ Outdoor education ☐ Visit historical site ☐ Cultural traditions ☐ Science	LIFESTYLE ☐ Fish ☐ Hunt ☐ Gather or Forage ☐ Collect gems/rocks ☐ Horseback riding ☐ Stewardship/volunteer ☐ Spiritual ☐ Therapeutic/health	LEISURE ☐ Scenic Drive ☐ Camp ☐ Relax ☐ Picnic ☐ Family ☐ Social event ☐ Resort
LIVELIHOOD ☐ Guiding ☐ Mining ☐ Grazing ☐ Work ☐ Forest products ☐ Firewood	ACTIVE RECREATION ☐ Raft/kayak/canoe ☐ Hike/walk ☐ Backpack ☐ Rock climb ☐ Bike ☐ Ski/Snowshoe	MOTORIZED ☐ Motorcycle ☐ Off-highway vehicles ☐ Motorized boating ☐ Snow machine ☐ Other: _____

1.4 Features: What site features attract you to this particular area? [e.g., canyon, river, gulches, forest, woodland, springs, streams, habitats, landscape, scenery, accessibility, facilities, available resources.]

1.5 Changes: What changes have you observed in this area? [Wildlife habitat? physical landscape? Air quality? Scenic quality? Social environment?]

FIGURE 4. Resource interaction questions.

ended when table groups joined for a facilitated discussion regarding their special places and the challenges and opportunities related to management of these places.

The online listening session provided an opportunity to engage members of the public unable to attend a local listening session, and replicated both methods used at the live sessions. Online participants could also map up to five resource interaction areas, but here by either placing a point or drawing a polygon on the interactive web map. Users could zoom in and out, or pan across the base map in a dynamic interaction. Participants then answered the same follow-up questions regarding the area as used in live listening sessions. For the special places, online participants could again map up to three special places with a point and answer the same follow-up questions regarding the name, significance, or meaning, and choose from the list of 17 landscape values or benefits they assign to the place. All text responses and map feature geometries were stored in a SQL Server database.

After data collection, the resource interaction polygons and special places points were manually digitized using ArcGIS software and stored in separate file geodatabase feature classes. Attribute data for the resource interaction polygons and special places points were stored in Excel spreadsheets with unique identifier fields to join attribute data to the spatial features. For the online data, the shapes and locations users drew for the resource interaction areas and special places points were converted from the GeoJSON format into a separate geodatabase. Attribute data about these shapes were imported from CSV files into geodatabase files.

To map these data, all 623 overlapping resource interaction polygons were intersected and broken into the minimum unit size, duplicate polygons removed, and the number of overlapping polygons counted for each new shape (Figure 6). These were shaded from light to dark to show concentrations in the areas of use. We could then disaggre-

gate responses based on numerous criteria, such as individual resource interaction categories, local versus non-local users, gender, season of year, or frequency of visits.

Special places were mapped by participants as dots on the maps. In order to better visualize areas where these dots concentrate, we generated density surfaces using a kernel density analysis. We first generated a 2,000 m search radius around each special place dot, then calculated the number of special places per square mile within the search radius. Next all search radius values were combined to create a composite density surface where each 10×10 m pixel has a value for the number of special places per square mile. This density surface was then shaded from light to dark [28].

Place #1 Name/Location of Special Place: _____

1.1 Meaning: Why is it significant to you? What does this place mean to you?

1.2 Landscape Values: What values or benefits to you associate with this place? Check up to 3 from the list below.

☐ Economic/Income	☐ Cultural
☐ Hunting/Fishing	☐ Ecological/Wildlife/Aquatic
☐ Recreation/Adventure	☐ Solitude/Sounds/Quiet
☐ Relaxation	☐ Spiritual/Religious
☐ Gathering/Foraging	☐ Fitness/Wellness
☐ Discovery/Learning	☐ Symbolic
☐ Scenery/Views	☐ Scientific
☐ Family/Social	☐ Beauty
☐ Historic	☐ Other: _____

FIGURE 5. Special places questions.

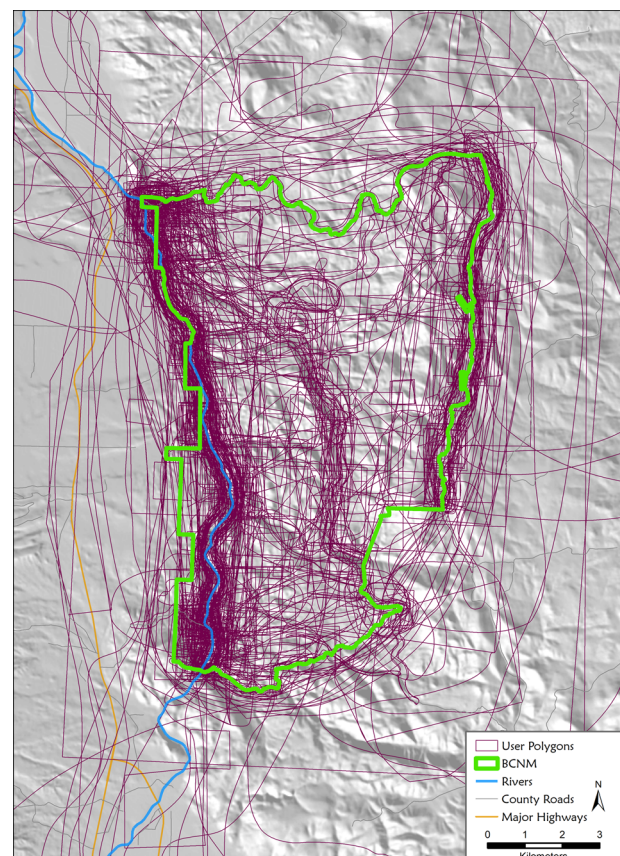


FIGURE 6. The messy raw data drawn by users—623 individual polygons. When thinking of their interaction with the BCNM, participants were encouraged to include regional places that they consider part of the overall experience. Some chose the nearby towns of Buena Vista and Salida, others chose the towering mountains of the Sawatch Range across the valley, as places that they intertwine with their understanding of Browns Canyon. For this reason, lines frequently extend far beyond the boundaries of the actual monument.

RESULTS

Resource Interactions

The map of all resource interactions shows concentrations of use along the Arkansas River, especially at the two primary access points for the monument at Ruby Mountain in the north and Hecla Junction in the south (Figure 7). Some concentrations also show along the Aspen Ridge unpaved road that traverses the eastern boundary of the monument. There are also lesser, but still visible, concentrations of use in the northern areas along designated hiking trails. Much of the interior of the monument is remote and difficult to access, and therefore shows fewer resource interactions.

We summarized the frequency of each resource interaction (Table 1), and then mapped each of the resource interactions individually. The spatial patterns for many of these, particularly the most popular interaction types, replicate the map of all resource interactions. However, some activities show very distinct areas of concentration that provide invaluable information for land managers to plan for appropriate uses at different places in the monument for these activities (Figure 8).

Looking at these patterns of concentration for different interactions allows land managers to better correlate the meanings certain places have for people to activities they engage in. For example, we see a strong spatial correlation between backpacking and a spiritual connection to place (Figure 9). Similarly, rafting and the river corridor itself appears highly correlated to therapeutic benefits from the landscape (Figure 10).

Finally, other types of disaggregation further help land managers plan for use of the monument. For example, there are strong differences in the use of space between summer and winter (Figure 11). We also see distinct differences in uses of

the monument among local residents, where Salida residents show detailed exploration of remote interior stretches of the monument, whereas Buena Vista residents tend to aggregate more along the river and Aspen Ridge corridors (Figure 12).

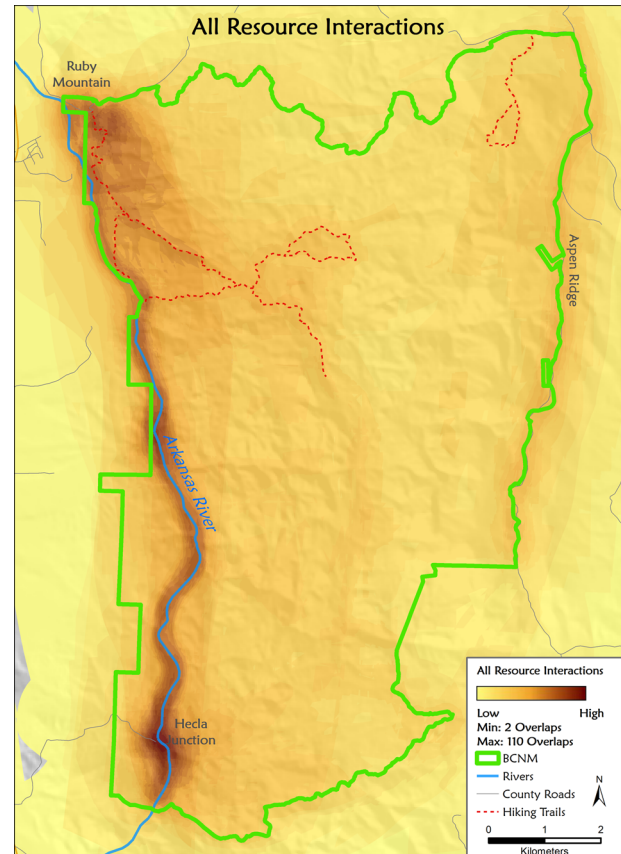


FIGURE 7. Shaded map showing concentrations of all resource interactions.

TABLE 1. Top 10 Resource Interaction Responses (623 respondents listed a total of 4,825 resource interactions).

Rank	Resource Interaction	Number	Percent of all Places Drawn that List this Interaction	Percent of all Interactions Listed by Participants
1	View nature	458	73.5	9.5
2	Hike/walk	406	65.1	8.4
3	Watch wildlife	302	48.5	6.3
4	Photography/art	270	43.3	5.6
5	Relax	250	40.1	5.2
6	Camp	218	35.0	4.5
7	Raft/kayak/canoe	202	32.4	4.2
8	Bird watching	200	31.0	4.1
9	Picnic	183	29.4	3.8
10	Family	171	27.4	3.5

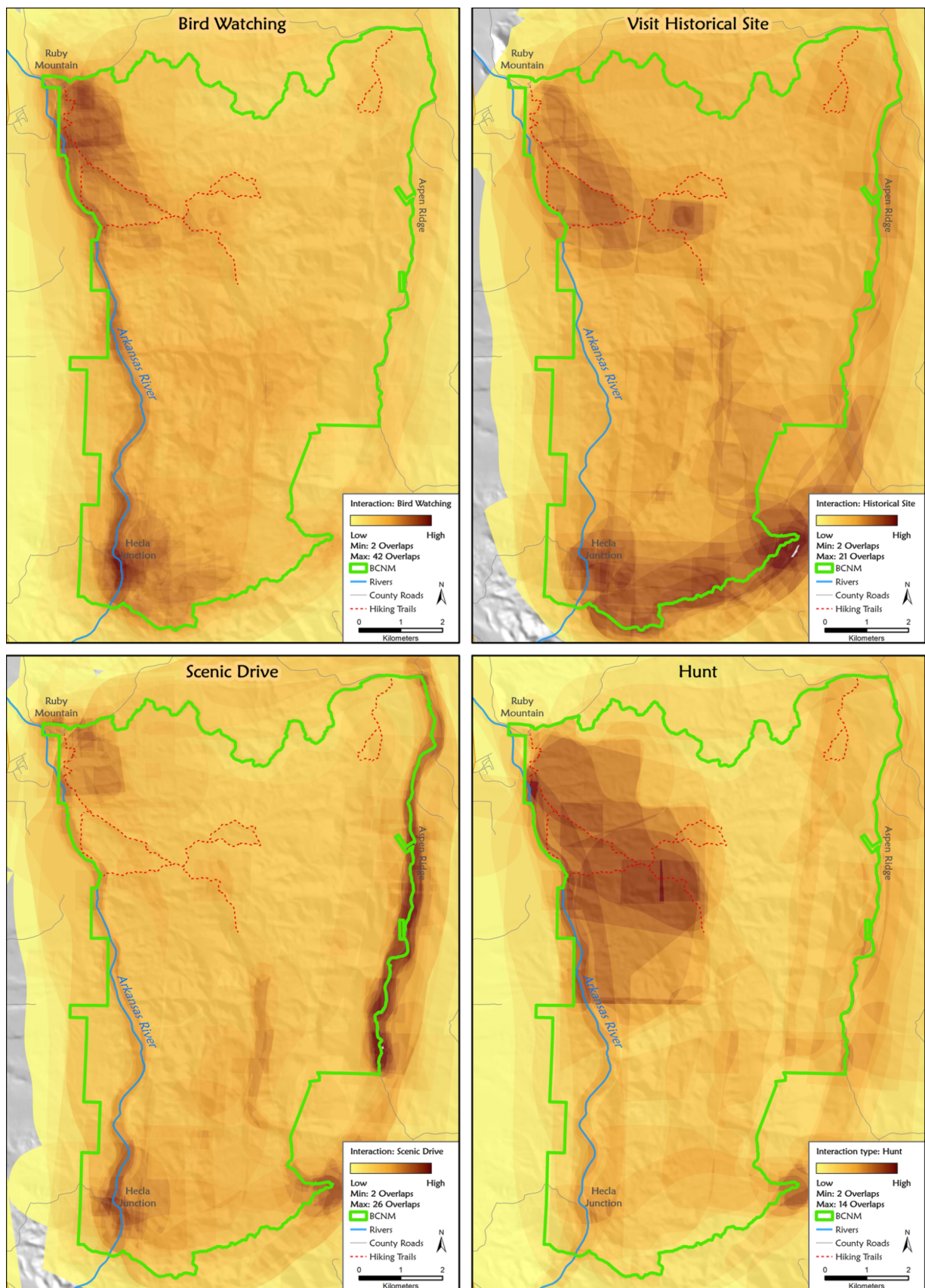


FIGURE 8. Examples of distinctly different patterns of resource interactions.

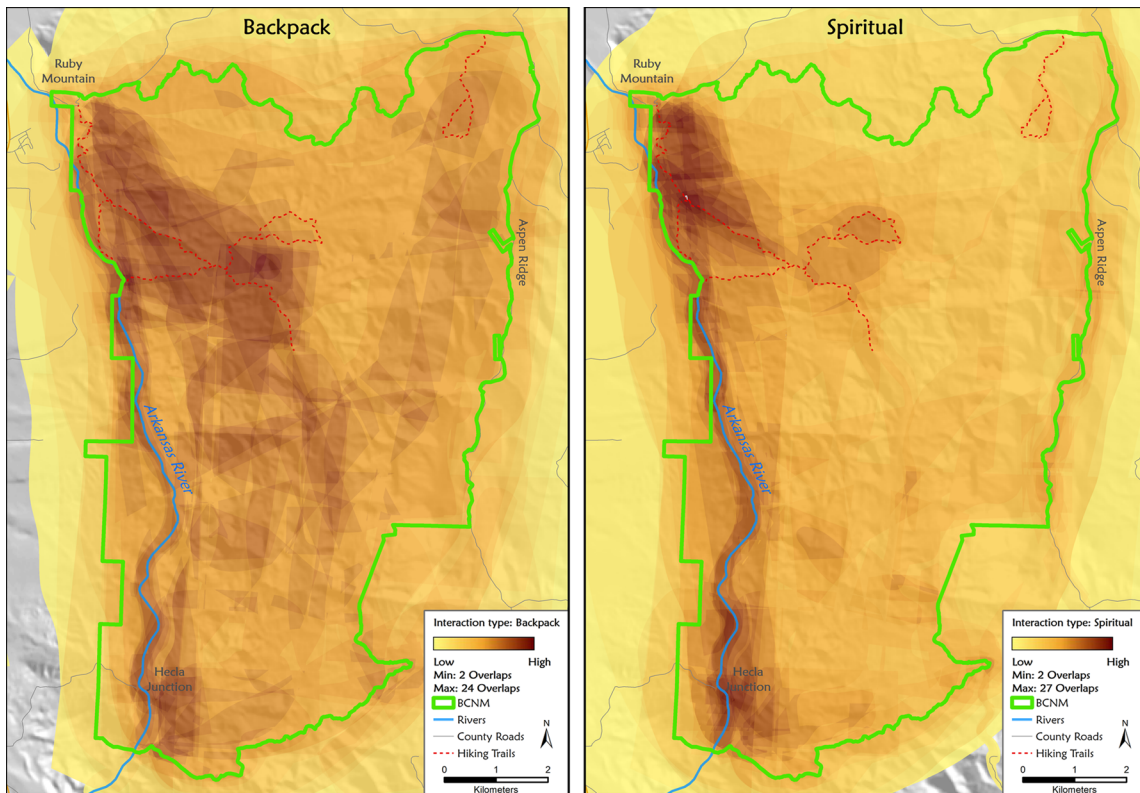


FIGURE 9. Activity-oriented backpacking correlates with spiritual place interactions.

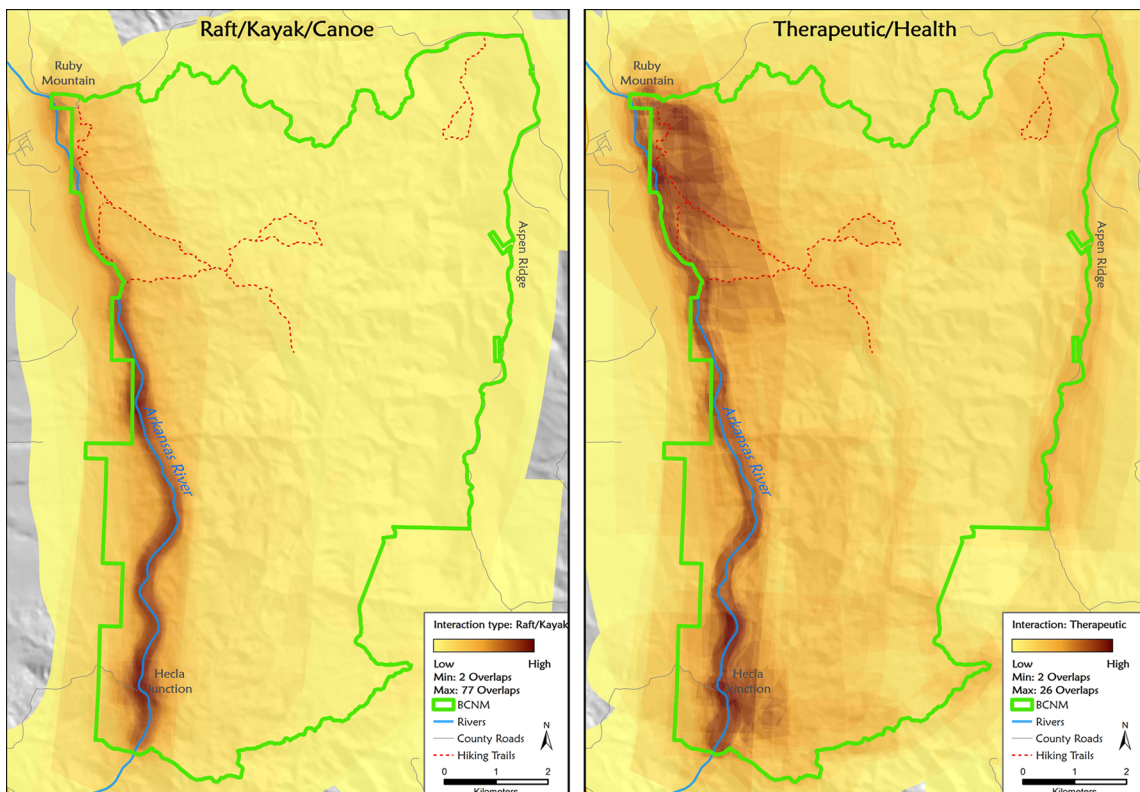


FIGURE 10. Rafting and kayaking relate to therapeutic landscapes.

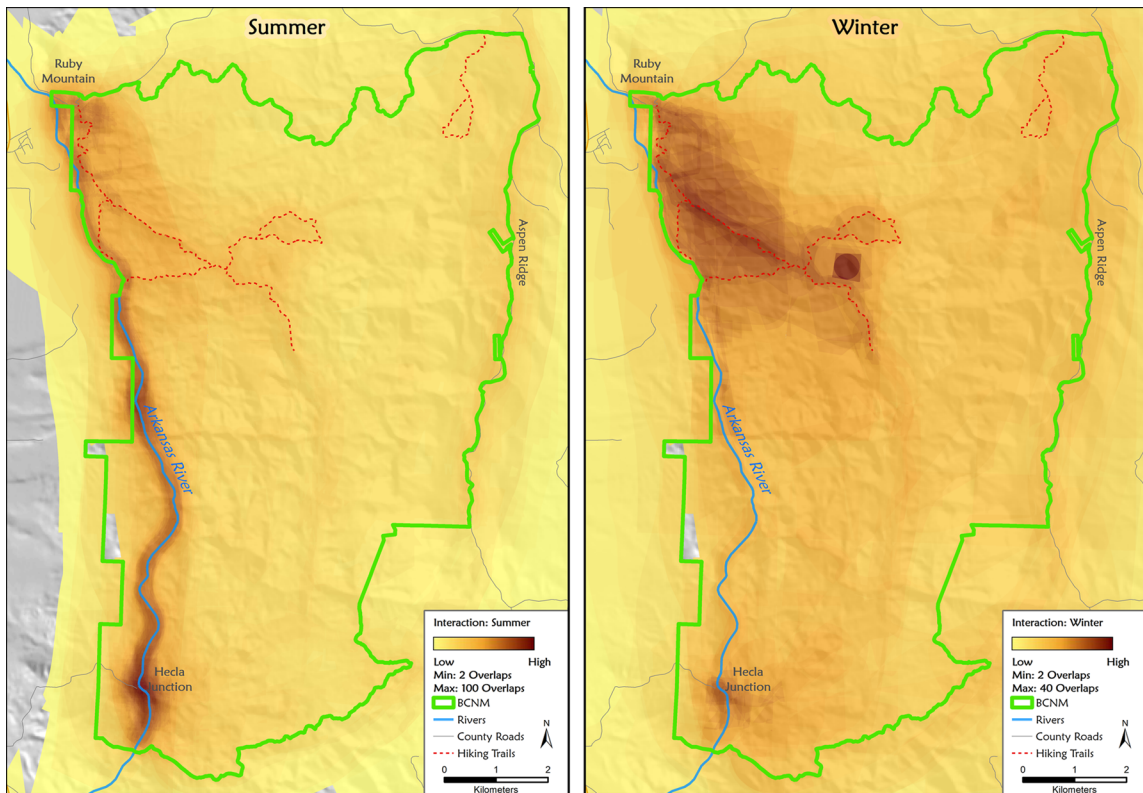


FIGURE 11. Very different use patterns between summer and winter.

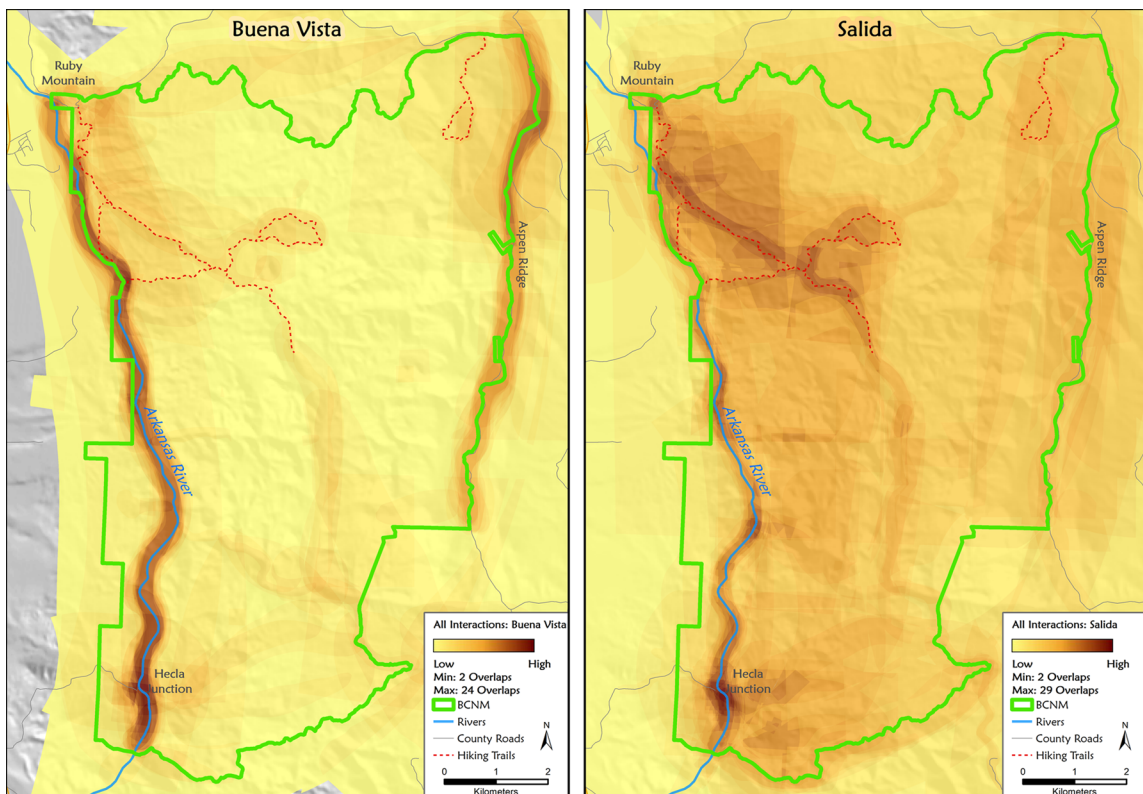


FIGURE 12. Different use patterns for residents of the two nearby towns.

Special Places

The Density surface map for all special places shows concentrations around the Ruby Mountain and Hecla Junction access points to the monument, reflecting places most familiar to the public (Figure 13). We calculated the frequency of each special place landscape value (Table 2) and mapped the density surfaces for each of these. Some of these reflect the patterns seen in the map of all special places, but others show varied concentrations (Figure 14).

While the differences in map patterns between community listening sessions and online participants were minimal with the resource interactions, they were quite pronounced for the special places (Figure 15). Both groups identify with Ruby Mountain in the north, but live participants really focus on the Railroad Gulch area in the far south whereas online participants seem to have a more general connection with the Arkansas River, with dots placed in the middle of the river corridor. Finally, local residents (53% of all responses) produced very different patterns than non-local respondents, who again tended to focus on the Arkansas River more generally (Figure 16). Such patterns help land managers to understand how different users perceive the space in different ways, and more detailed data analysis can further disentangle perceptions associated with different characteristics of respondents.

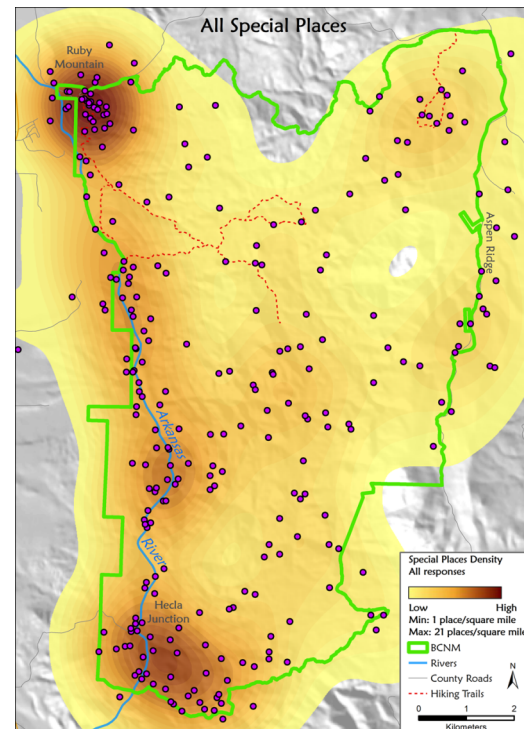


FIGURE 13. Surface shades showing densities of all special places per square mile.

TABLE 2. Landscape values associated with special places (312 special places were mapped with a total of 1,611 landscape values identified).

Rank	Landscape Values	Number	Percent of Special Places that List this Landscape Value	Percent of all Landscape Values Identified
1	Recreation/adventure	237	76.0	14.7
2	Scenery/views	184	59.0	11.4
3	Relaxation	166	53.2	10.3
4	Solitude/sounds/quiet	137	43.9	8.5
5	Ecological/wildlife/aquatic	107	34.3	6.6
6	Discovery/learning	101	32.4	6.3
7	Fitness/wellness	98	31.4	6.1
8	Family/social	89	28.5	5.5
9	Beauty	86	27.6	5.3
10	Historic	69	22.1	4.3
11	Spiritual/religious	64	20.5	4.0
12	Economic/income	56	17.9	3.5
13	Symbolic	55	17.6	3.4
14	Hunting/fishing	54	17.3	3.4
15	Scientific	43	13.8	2.7
16	Cultural	41	13.1	2.5
17	Gathering/foraging	24	7.7	1.5

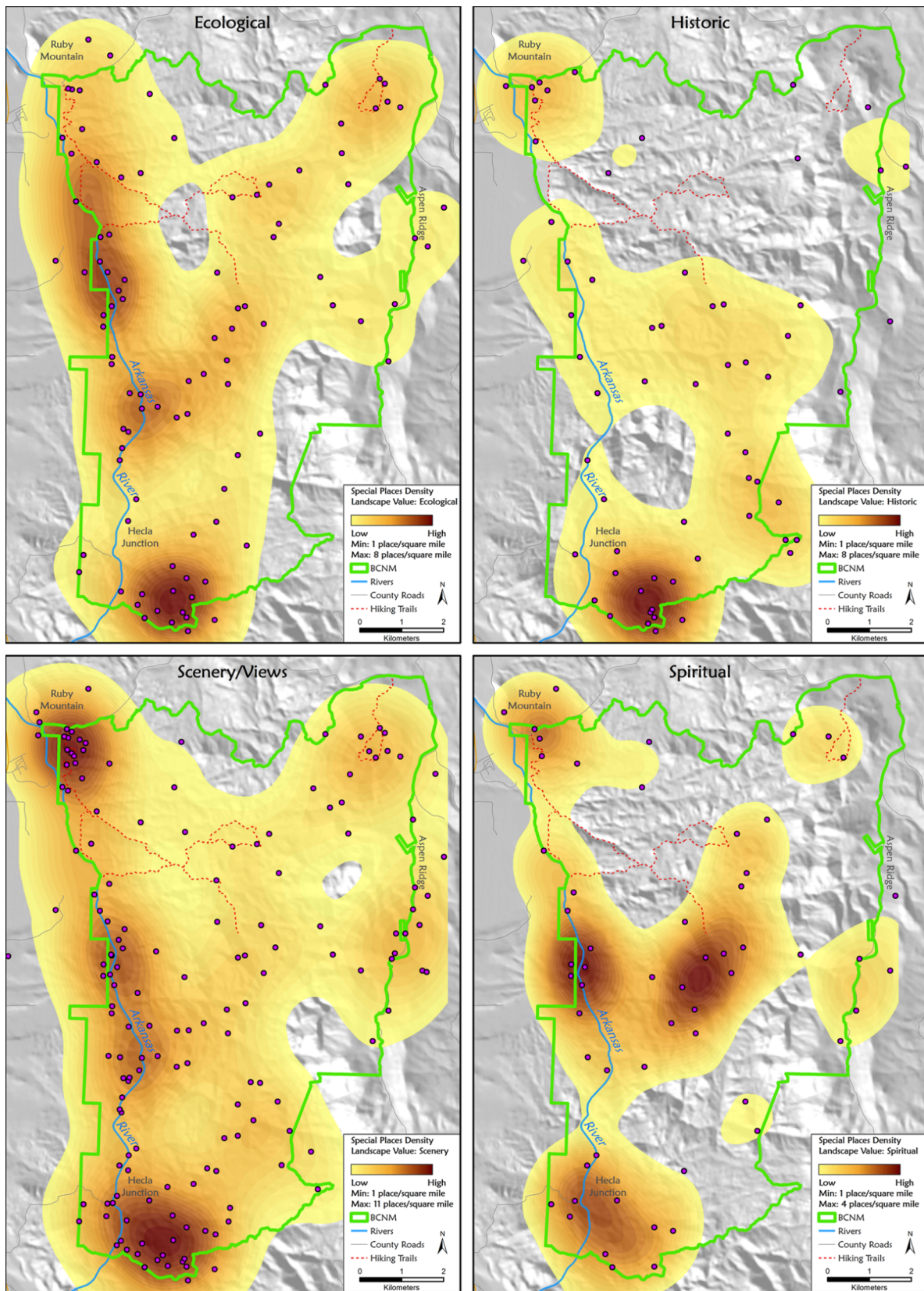


FIGURE 14. Examples of distinctly different patterns of special place concentrations.

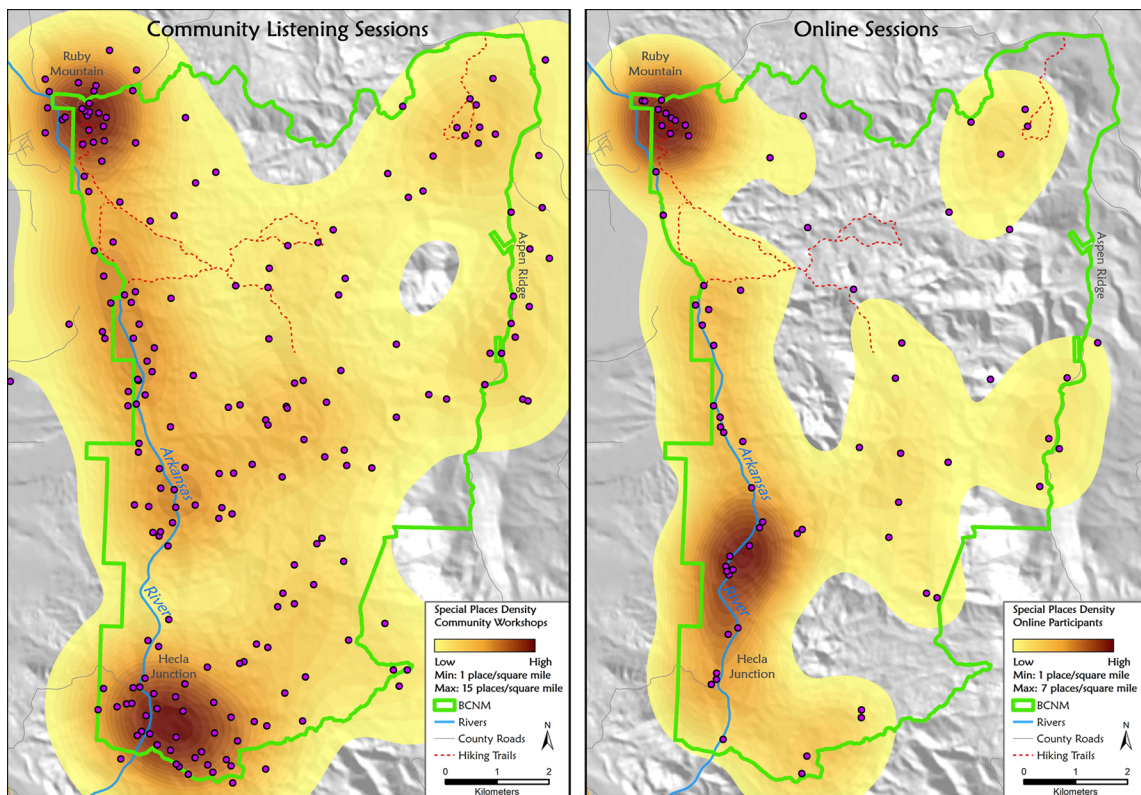


FIGURE 15. Special places selected in Live Community Workshops versus Online choices.

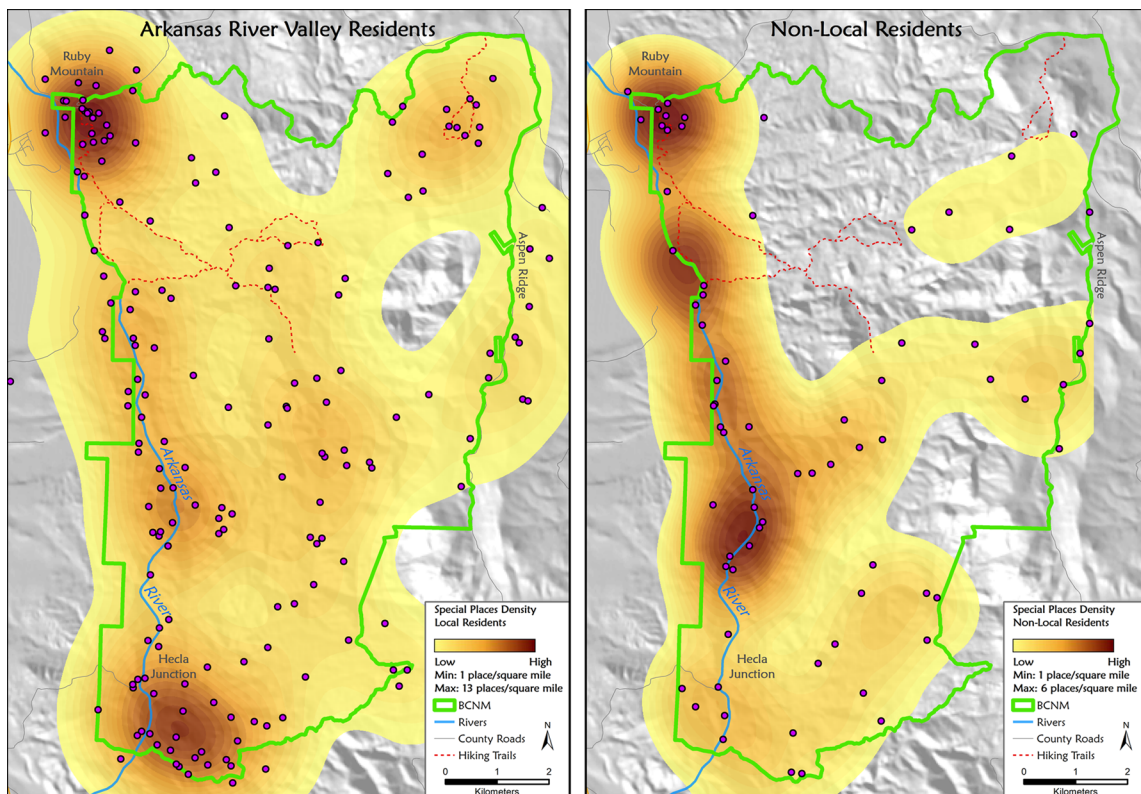


FIGURE 16. Local versus non-local choices of special places.



FIGURE 17. Follow up community meeting in Salida to present initial results. Photo by Harner.

DISCUSSION

The purpose of this project was to gather information from the public about how they interact with the lands in the new Browns Canyon National Monument and what meaning and values these places have. Land managers in the past were forced to begin the process of developing land management plans with almost none of this information. With participatory mapping, land managers now have data to guide their planning.

Following on Brown and Reed's recommendations to start data collection early in the planning process and work with the explicit support of the federal land management agencies, this project was conducted in the pre-planning, or visioning stage, of land management planning under the direct guidance of the BLM. This is prior to developing the land management plan and can be considered as data input to that process. Utilizing this protocol at the earliest stages and with the active promotion

by BLM and USFS land managers ensured community cooperation and active participation. In what is often a contentious process, we encountered no resistance to the process, and land managers now have valuable information to develop a robust plan sensitive to stakeholder concerns. We also sought data from multiple stakeholders by complementing the community workshops with the online tool. Despite multiple platforms for gathering data, we recognize that participants are not a representative sample of the overall population, given that this self-selected group is more likely to be comprised of people with existing interests in the monument. We also had a bias of 69% male respondents for both the online and community-based sessions, which, while disproportional to the American population, is reflective of the population that actually uses nearby national forest lands [29]. Despite these biases and limitations, the process generated valuable data from users of the monument that federal agents would

otherwise not have. Finally, in order to address the pros and cons of asking participants to identify locations using either dots or hand-drawn polygons, we utilized both representations. Our case study does this by presenting both resource interaction polygons with special places density surfaces derived from dots. Users can see the differences these two methods create and assess for themselves which reflects their understandings better.

A follow up meeting was held in Salida in May, 2017, to present initial results to the public and explain the overall planning timeline for the BCNM management plan. Results were well received (Figure 17). Some members of the public inquired as to why their personal responses were not visible, and the research team explained that these maps reflect an aggregation of all data, with patterns emerging from the “wisdom of the crowds” rather than any one stakeholder [30]. These public comments did, however, spark ideas about further presentation of data, such as overlaying individually-identified places and comments onto the background of the aggregate results. For example, highlighting specific responses informs somewhat vague resource interaction categories like historic sites (Figure 18) and does the same for more and even more well-defined interactions like mining or gem and rock collecting (Figure 19). We can also overlay individual responses to look for spatial correlations between the specific resource interactions and the more esoteric special places for inductive, data-exploratory investigation. For example, we can overlay very detailed comments about scenic beauty drawn in the resource interactions mapping activity with the density maps of scenery identified as special places (Figure 20), or also comments on wildlife and biodiversity interactions with the density map of ecological special places (Figure 21). The feedback sessions provided confirmation for the participatory mapping process and the additional interaction helped to expand trust between area residents, agency officials, and the study team.

This case study illustrates the power of visualizing uses and perceptions of place. Maps also reveal spatial correlations between different uses. The BLM intends to further disseminate results with an online Story Map, which provides a limited measure of user interactivity. The next step would be to make user responses and aggregate map data available for the public to query and explore in a fully interactive website, where users could browse through public responses and turn shapes on or off, overlay different layers, and discover spatial relationships on their own. Technologies exist for such a site, but require much custom programming and development. With

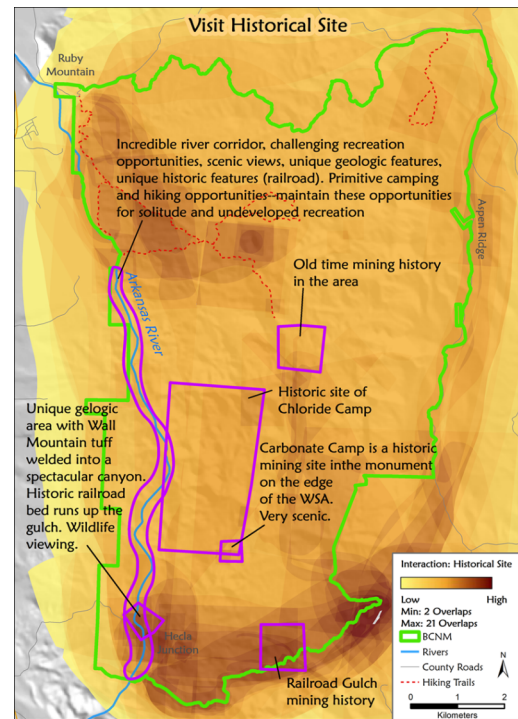


FIGURE 18. Individual comments on resource interaction polygons clarify thematic map layers.

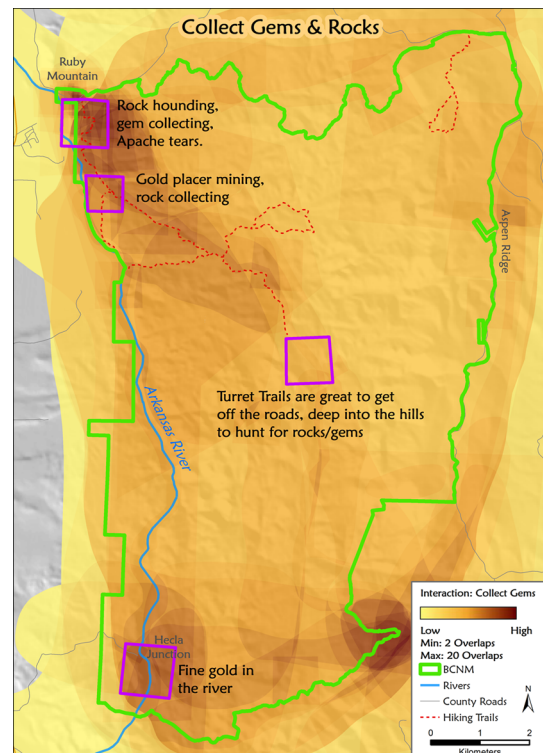


FIGURE 19. User comments also illustrate more utilitarian resource interactions. The term “Apache Tears” refers to small, rounded pebbles of black obsidian.

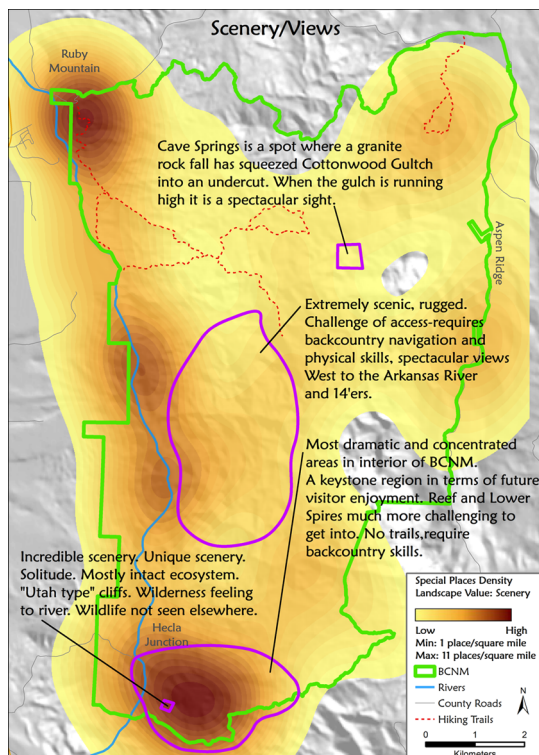


FIGURE 20. Individual resource use comments can be used to illuminate special place meanings as well.

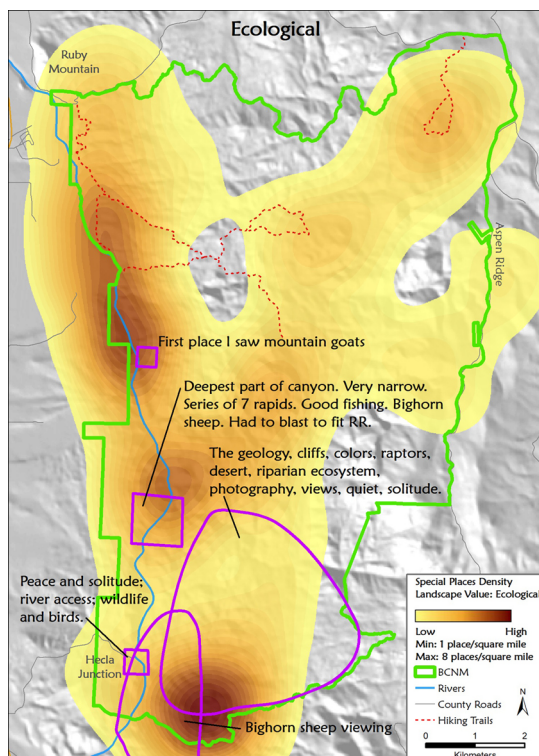


FIGURE 21. Resource use interactions illustrate ecological special places.

ever-evolving geospatial online mapping tools, we can expect such products to become more readily available and finely tuned. For now, the most important outcome of this project is that the BLM will take the HEM results and incorporate them into the next phase of the planning process, for the first time with a rich diversity of valuable data derived from public input.

CASE STUDY QUESTIONS

1. What options and instructions would you give public participants to assist them in identifying locations on a map with the most accuracy?
2. The hope is that public participants interpret the meanings of individual resource interactions (e.g., View Nature, Relax) and the Special Places Landscape Values (e.g., Scenery/Views, Symbolic) similarly among themselves. What options and instructions would you use to ensure public participants interpret these in a consistent way?
3. What other ways could the data be disaggregated and analyzed to show relationships that might otherwise not be seen?
4. How would you modify the research protocol to get better representation of the entire public?
5. How would these results be best shared with the public?

AUTHOR CONTRIBUTIONS

John Harner: conceptualization, methodology, validation, formal analysis, investigation, resources, writing draft, writing review, visualization, supervision, project administration, funding acquisition

Lee Cerveny: conceptualization, methodology, investigation, resources, writing draft, writing review, visualization, project administration

Rebecca Gronewold: methodology, validation, investigation, data curation, writing draft, writing review, visualization

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COMPETING INTERESTS

The authors have declared that no competing interests exist.

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