Mapping Recreation - Wildlife Overlap in the Backcountry

Submitted as partial fulfilment of a Master's of Science in Geospatial Technologies

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Abstract

Due to the far-reaching influences of social media & the recreation industry, there has been a significant increase in the number of people recreating outside on public lands. People are increasingly aware that outdoor recreation provides an escape, increases fitness, and raises vitamin D levels, but the negative wildlife impacts of an ever-growing outdoor recreation populace tend to be more subtle. Big recreation numbers can lead to displacement, increased stress, lowered productivity, and even increased mortality for wildlife. While lottery systems and permit reservations have helped mitigate some negative impacts, it is vital to make recreationists aware of the sensitive wildlife habitat they travel through in the backcountry. In an increasingly technology-dependent society, one way to decrease the environmental stress brought on by waves of recreationists is to leverage technology to educate the recreating public and increase their backcountry situational awareness. This project intends to alleviate recreational impacts on wildlife via the implementation of a mobile-friendly, web-based GIS application that highlights seasonally sensitive wildlife habitat during relevant time periods. Additionally, the app will integrate a data collection module that will enable users to report wildlife sightings while in the backcountry. The application will pull from a variety of government and non-government organization data sources (wildlife habitat, seasonal closures, etc.) to create up to date layers indicating areas of conflict for recreationists. Recreationists using this application can be better prepared prior to heading out, more situationally aware while on their adventures, and empowered to be a part of wildlife conservation while engaging in their favourite activities.

1. Introduction

In a still growing nation, Washington is one of the fastest growing states. According to the World Population Review, Washington's population grew by 18.96% from 6,724,540 people in 2010 to approximately 7,999,503 people in 2023 – a rate placing Washington as the 7th fastest growing state in the nation. Moreover, the Washington State Office of Financial Management predicts the state's population to reach 9 million by 2037 and 10 million by roughly 2050. There are a host of reasons for this growth, including a strong economy, low poverty rate, no state income tax, and a unique scenic beauty not found elsewhere in the Contiguous United States.

Considering Washington's scenic beauty, it is no surprise that many newcomers are eager to get outside and experience what Washington has to offer. Estimates show that Washingtonians spend $26.5 billion on outdoor recreation annually (Mojica, J., Fletcher, A., 2020). To boot, that spending supports 264,000 jobs totalling $12 billion in wages for

Washington State workers (Mojica, J., Fletcher, A., 2020). The numbers emphasize the outdoor recreation industry's significance in Washington State and reflect the reality that being outside is a way of life in the "Upper Left" portion of the United States.

Despite the enthusiasm surrounding outdoor recreation in Washington, there are some concerns in the conservation community. Prominent among those concerns is the effect of booming recreation on the native fauna who inhabit public lands. Namely, there are increasing concerns pertaining to the effects of outdoor recreation on wildlife's ability to reproduce and survive in their own habitat. According to Backcountry Hunters and Anglers, animals fleeing from recreationists experience "increased heart rate and stress from such disturbances can be energetically costly especially during gestation, calving, and essential foraging periods and seasons. Fleeing or hiding in dark timber means less time foraging and food uptake essential to winter survivability and may cause a decrease in cow to calf ratios" (Parker, 2022).

This project will focus on ways in which Geographic Information Systems (GIS) can be used to mitigate some of the impacts of recreation on wildlife. I aim to mitigate these impacts via the development of a mobile-friendly web application that operates in a dual capacity. On one end, the app will use existing wildlife data to visualize sensitive wildlife habitat temporally and spatially for backcountry travellers. On the other end, the application will enable backcountry enthusiasts to conduct citizen science by reporting wildlife sightings/interactions via a user-friendly mobile data collection interface. The end goal is to create more situationally aware recreationists who feel empowered in the mitigation of negative wildlife impacts.

2. Literature Review

This section covers the three areas of research driving this project with an emphasis on the literature informing each area. The first section looks at the pros and cons commonly associated with increased access and use of public lands in the United States, aka the "Recreation Boom." Next, I will highlight habitat use patterns for the chosen species of focus for this project and examine how habitat use intersects with human recreational use. Lastly, I will explore previous cases of GIS implementation in wildlife management and dissect how GIS can be applied to this project.

2.1 Access to Public Lands – Pros & Cons

As discussed previously, the number of recreationists visiting public wild places in the United States has dramatically increased over the previous decade. The Seattle Times has reported that the number of Seattle-area hikers has doubled since 2008 and the number of Discover Passes (the pass required at many Washington State managed recreation areas) has gone from 417,000 sold in 2012 to 648,800 sold in 2017 (Balk, 2018). Whether it's via social media, television, or highly effective ad campaigns from the outdoor recreation and tourism industries, the word is out, and in the Pacific Northwest, "opting outside" is a way of life. Recreation's impacts on wildlife go beyond a mere numbers game though. People are now traveling further into the backcountry than had been the case in the past because of advancements in technology, whether it be advanced mountain bikes (or e-bikes), backcountry touring skis, navigation apps, motorized side by sides that can tackle just about any terrain encountered, or modern climbing equipment that makes scaling walls previously reserved for the boldest climbers now accessible for the weekend warrior.

For anyone hitting the trails or exploring the backcountry, it is no secret that the word has gotten out: Outdoor recreation is on the rise all over the world, and the Pacific Northwest is

among the premier outdoor destinations in the United States. A big part of this "Recreation Boom" is the numerous benefits outdoor recreation provides for human beings. Health benefits provided to people via outdoor recreation are well-known and include increased vitamin D, increased exercise length and regularity, fresh air to breathe, reduced obesity, decreased chronic disease, improved immune function, and increased life expectancy (California State Parks., 2005). In addition to direct human health benefits, studies show that outdoor recreation provides numerous mental health benefits, such as decreased depression, stress relief, and improved quality of life. Moreover, outdoor recreation has been attributed to the numerous societal benefits. Specifically, studies have shown recreation to strengthen communities through the promotion of stewardship/volunteering, promoting social bonds, and assisting in the development of youth. (California State Parks., 2005).

Health and community benefits are not the only positives that proponents for outdoor recreation point toward. As the number of recreationists has climbed, so has the economic influence of the outdoor recreation industry. As stated by the Washington State Recreation and Conservation Office, recreation in Washington State is "big business" and purportedly generates $26.5 billion annually from direct consumer spending, supporting 264,000 jobs (Nelson et al., 2021). The substantial economic power of outdoor recreation tourism has been cited as justification for "building more trails, especially multi-day trails that bring in more revenue, improving existing trails, and developing more uniformity in permitting requirements to streamline new trail development" (Nelson et al., 2021).

Increased access to outdoor recreation has also commonly been promoted as a savior for struggling rural economies. In August of 2022, the Biden-Harris Administration released a statement announcing their intention to bolster the economies of 25 small and rural communities from across the country by growing their outdoor recreation economies through the Recreation Economy for Rural Communities (RERC) program (EPA, 2022). These types of initiatives have become increasingly common as recreation numbers boom and rural communities economically wounded by the reduction of traditional resource extraction industry activity search for alternative means of survival.

Despite the aforementioned benefits, the recreation boom has presented challenges and growing pains. As the limited current research on impacts of recreation catches up to the research on the benefits of recreation, there is a growing list of concerns regarding public wildlands. As Sarah Krakoff states in *Mountains Without Handrails… Wilderness Without Cellphones*, "Yet on closer inspection, it appears that nature-the idea, the place, the community of life-is being displaced and even threatened by something more akin to Nature TM, or Nature@, the product." (Krakoff, 2003). Has outdoor access created another way for humans to commodify nature? Are we loving our wild spaces to death? Are we watching the modern-day Tragedy of the Commons unfold right before our eyes?

From a human perspective, there are increasing concerns about access becoming an issue. For one, as mentioned previously, the outdoor recreation industry has touted the positive economic impacts of increased recreational access on rural communities; however, not all rural communities share that enthusiasm. For example, in Arizona, conflicts between ranchers and newcomers drawn by recreational opportunities have resulted in resentment and territorialization as locals fear for their way of life being threatened as new residential sprawl consumes open space while increasing traffic and noise (Brogden, Greenburg, 2003).

Furthermore, concerns about the quality of experience have spread from town to the wilds themselves over the years. Reservation systems have become increasingly common as land managers attempt to limit crowds and preserve the user experience. For instance, beginning in the summer of 2021, three popular wilderness areas in Western Oregon - the Three Sisters, Mount Jefferson and Mount Washington wilderness areas – began requiring both day-use and overnight users to obtain a wilderness permit (NW News, 2021). This is just one example, as

similar reservation systems have been put in place at other National Parks and Forests around the country. Recently, there have even been bills introduced to address crowding on public lands, as is the case with the Gateway Community and Recreation Enhancement Act introduced by U.S. Senators Steve Daines (R-Mont.) and Angus King (I-Maine) to "reduce traffic in our nation's most popular national parks, while shining an overdue spotlight on some of the country's hidden jewels" (Congressional Documents and Publications, 2022).

On the other hand, the Wenaha Wild and Scenic River, beginning in the Wenaha-Tucannon Wilderness Area within the Umatilla National Forest of northeastern Oregon, has also conducted studies on recreational user experience satisfaction and received results showing minimal crowding and high user satisfaction (Burns, et al., 2018). These studies seem to indicate the effect of access on user experience. Access to the Three Sisters Wilderness is easy and within a reasonable distance of several large population centers, whereas the Wenaha Wild and Scenic River's main access point is in Troy, OR – a discreet, highly remote canyon community hours away from any major population centers.

2.2 Wildlife - Human Interactions

While frustrations for rural residents and decreased visitor satisfaction for wilderness recreators have become a concern, perhaps the most substantial negative effect of the modern outdoor recreation boom is its potential consequences for wildlife. Generally, "the effects of recreation on wildlife are mostly negative; animals tended to have stronger responses to less predictable forms of recreation; reproductive status was important for individuals encountering recreation; seasonal responses differed between summer and winter; and habitat generalists were typically less vulnerable than habitat specialists." (Machowicz, et al., 2022). Why have recreational impacts on wildlife been ignored by much of the public despite data to the contrary?

One reason could be that most recreationists simply do not think their activities of choice have much of an impact – especially activities deemed to be non-consumptive. In a study from 2003 that polled 640 backcountry trail users, 50% of the people surveyed believed their form of recreation had no negative effects on wildlife and shifted the blame to other user groups – particularly motorized user groups (Taylor and Knight 2003). It's not uncommon for motorized recreation to be the target of blame for recreational impacts on public wild spaces and there is ample research spotlighting negative impacts of motorized recreation on wildlife. For example, studies have shown that motorized recreation causes displacement and avoidance where animals altered their use of habitats in response to motorized trails or trail networks (Gaines, et al., 2003).

However, the public's perception that "non-consumptive" recreation is benign with regards to wildlife is increasingly being challenged by the science, despite a long-standing assumption that human-powered recreation is compatible with biodiversity conservation. In a 2016 review of over 274 articles on the effects of non-consumptive recreation on animals, across all geographic areas, taxonomic groups, and recreation activities, researchers discovered that "Counter to public perception, non-motorized activities had more evidence for a negative effect of recreation than motorized activities, with effects observed 1.2 times more frequently." To boot, snow-based activities had effects observed 1.3 times more frequently (Crooks, et al., 2016). How does non-consumptive recreation impact wildlife?

With greater numbers of people forging their way further into the backcountry, the intersection between wildlife habitat and recreational activities has widened. This creates issues for wildlife. Literature shows that non-consumptive recreation can result in altered spatiotemporal habitat use, decreased survival and reproduction and, ultimately, decreased population abundance, or extirpation from otherwise suitable habitat for terrestrial wildlife (Dertien, et al., 2021). Moreover, with the predictability of human powered outdoor

recreation decreasing (i.e., an increase in off-trail/cross-country travel), animal response to recreational disturbance is likely to be stronger (Cole, et al., 2003). With population growth in Washington State showing no signs of slowing down any time soon, it can be assumed that the volume of outdoor recreational use will also continue to climb. With that in mind, what can be done to leverage modern technology to assist in this modern dilemma?

2.3 GIS in Wildlife & Recreation

As alluded to earlier in this literature review, mapping products are among the technology currently enabling recreationists to push further into the backcountry whether it be on foot, motorcycle, or ski. Mapping applications such as Gaia GPS, Hiking Project, onX, and Caltopo have made the furthest depths of America's wilderness accessible to the weekend adventurer. On the flip side, geographic technology is also routinely used to manage public lands while conserving wildlife. Geographic Information System (GIS) data can be used to point out areas of wildlife habitat and recreation overlap, highlight critical habitat, map trails/roads, and point out popular off-trail areas. The following paragraphs will highlight a couple of specific cases where GIS was used to improve land and wildlife management decisions.

Citing similar reasons to those listed previously in this text (the rapid growth of winter recreation stemming from technological advancements making the far reaches of the backcountry accessible for large numbers of people), Olsen et al. (2017) modeled terrain selection of motorized and non-motorized recreationists in an attempt to better understand recreation conditions chosen by winter enthusiasts. A combination of GPS tracks, created by recreationists, and remotely sensed topography, vegetation, climate, and road access characteristics were modeled to create spatial products depicting possible places of ecological disturbance and conflicts between motorized and non-motorized user groups (Olson, et al., 2017). The results of this study enable land managers to "maintain winter recreation opportunities while reducing interpersonal conflict or ecological impacts to sensitive wildlife" (p. 66).

Another source of increased accessibility to wild spaces has been social media. Prominent social media sources, such as Instagram, Facebook, and Twitter have changed the outdoor landscape. Once "off the grid" locations are now known by the masses and are regularly featured in the photos and stories of social media "content creators." Part of that created content is the implementation of geotagging in photos. As is typical, there are two sides to the coin and the same geotagging increasing visitation to formerly secret locations can be used to gain a spatial understanding of public land visitation and map the results. This is exactly what Zhang, et al. did in their 2020 investigation into the visitation patterns of Utah's national parks, national forests, and state parks. The authors performed their analysis at the statewide, regional, and county scales in order to demonstrate, "how social media can serve as a useful tool to inform proactive planning and management efforts." (Zhang, et al., 2021, p. 1). Both prior articles exhibit ways in which GIS can be implemented to improve the relationship between outdoor recreation and terrestrial wildlife in public wild spaces. That too is the goal of this project.

3. Description of Application

As stated in the project objectives previously, one of the pillars of this project was to create a mobile-friendly, web-based GIS application that highlights seasonally sensitive wildlife habitat during relevant time periods. The name of my application is *Tread Lightly – Promoting Wildlife Conscious Recreation in Washington State*. Tread Lightly focuses on 7 select species: black bears, elk, deer, bighorn sheep, Canada lynx, wolverines, and mountain goats. Each species has their own page in the app that displays habitat concentration areas,

sensitive seasonal habitat, and recreation overlap and contains charts breaking down approximate habitat acreages and percentages based off the data I obtained.

While the individual species pages are a vital part of the project, the 3D Backcountry Planner Application (BPA) is the main muscle of the project. The BPA displays United States Forest Service (USFS) and National Park Service (NPS) boundaries and trails layers to help the user begin planning their trip. Users can also click on recreation usage layers to visualize areas with the greatest number of trip reports or route reviews, draw routes complete with mileage and elevation gain statistics, and add their own layers to aid in decision making. Most importantly, seasonally sensitive wildlife habitat is mapped by species so users can see if or where their intended routes cross the path of seasonally sensitive habitat. Seasonality is defined monthly with all seasonally sensitive habitat layers falling in the current month being displayed in the app for the duration of that month.

4. Methods

I initially intended to complete my web application via a more open-source platform, such as Mapbox GL JS. However, after carefully considering the functionality, I was hoping to have within the application, along with reviewing several examples of similar applications, I decided to complete my project with ESRI's Experience Builder Developer Edition (EPDE). On paper, this option was the best of both worlds: ESRI provides a wide selection of customizable templates to ease design considerations, while drag and drop widgets implement my desired functionality without requiring large chunks of time to dedicated to learning more advanced coding. With all that said, the Developer Edition still provides avenues for application developers to customize features and functionality at the level desired by the user.

4.1 Data Gathering & Processing Data in ArcGIS Pro

Data for Tread Lightly came from both a variety of sources and in a variety of types. Geospatial data consisted of both vector and raster data. Foundational GIS data implemented in this project are as follows:

Table 1. Foundational Vector & Raster Layers used in *Tread Lightly*.

Layer Name/ Description	Data Type	Source
USFS Trails	Vector Line	USFS Open Data Portal
NPS Trails	Vector Line	NPS Open Data Portal
NLCD 2019 Land Cover	Raster	NLCD 2019 Land Cover (CONUS)
Wildlife Habitat Concentration Areas	Vector Polygon	WA Wildlife Habitat Connectivity Group
Washington State Boundary	Vector Polygon	Washington Geospatial Open Data Portal

In addition to geospatial data, this project repeatedly drew from more traditional research to create application layers. More specifically, creating Wildlife Habitat Concentration Layers for each of the 7 selected species required me to read about each species' habitat needs. The Washington State Department of Fish & Wildlife served as a primary source for this information through the "Species and Habitats" section of their website. When I still needed additional species habitat information, I filled in the gaps by enacting government publications and wildlife-focused non-government organization websites. The habitat

information from these sources was gathered to be included in the attributes for species-specific habitat layers.

Creating the sensitive habitat layers was a multi-step process that began by taking the Habitat Concentration Area polygons downloaded from the Washington Wildlife Habitat Connectivity Working Group's data layers. Habitat Concentration Area (HCA) polygons for each of the project's 7 focal species were added to a map in ArcGIS Pro for data preparation. Next, the 2019 National Land Cover Dataset (NLCD) raster was added to my ArcGIS Pro project. Both the 7 HCA polygons and the NLCD raster were then "clipped" (Extract by Mask in the case of the raster) using a Washington State Boundary polygon layer to trim the data to the focus area of my project – the State of Washington. These newly created layers were used to visualize habitat for my 7 species and land cover types across Washington.

Next, the NLCD raster was then "clipped" to match the extent of the 7 HCA layers using the Extract by Mask tool again. This is the point where wildlife literature research came into play on the GIS side of the house. Relying on what I learned in the literature, I created the sensitive habitat layers by identifying NLCD classifications that matched the sensitive habitat types identified in the literature. Some species, such as Canada Lynx, have only one sensitive habitat layer (in this case kittening habitat), while others like elk had several. I did not concern myself with each species having more than one sensitive habitat layer if it wasn't factual. Because the initial sensitive habitat layers were rasters, I used the Raster to Polygon tool to convert them to vector layers for the app. Last but not least, I used the Dissolve tool to compress what were thousands of rows of data for each sensitive habitat layer down to a row for each NLCD classification using the "gridcode" column as the dissolve field. Figure 1 shows a simple map visualizing elk wintering habitat overlayed on the elk HCA layer.

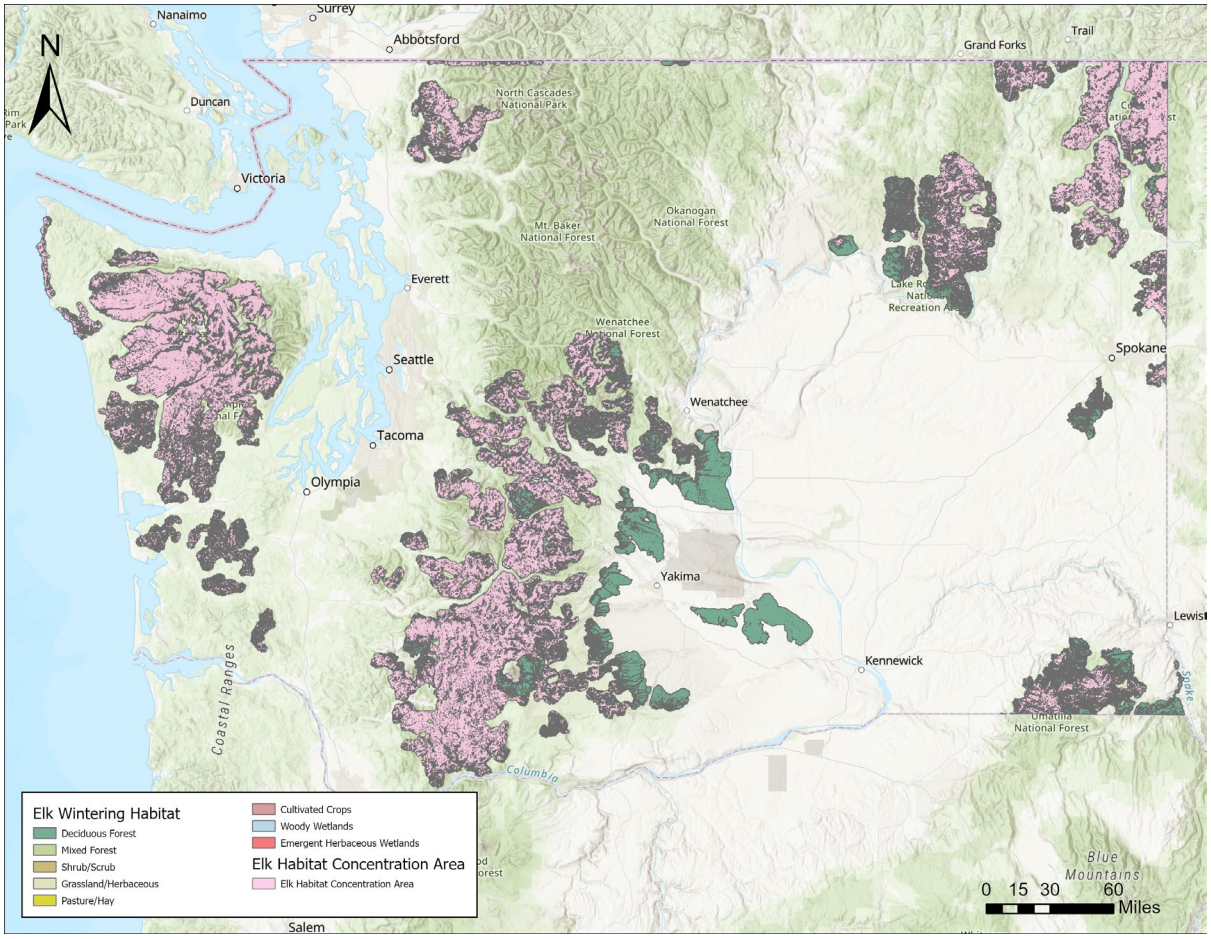

Figure 1. Elk wintering habitat.

Identifying and extracting the habitat types was only part of the sensitive habitat layer process. The temporal aspect of the data also needed to be incorporated into the attribute table of each layer. To accomplish this, I created "Start", "End", and "Months" columns for each sensitive habitat layer. The "Start" and "End" columns were formatted as date columns to enable time display in ArcGIS Online (AGOL) once they were uploaded and were hidden in pop-ups when I developed the web application. The "Months" column was formatted as a text field and used to inform users in pop-up windows in the *Tread Lightly* application. I also added an Acres column, calculated with the Calculate Geometry tool, and a picture column.

With the wildlife data taken care of, I needed to focus on the recreation side of the equation. I was able to use Python code provided in Yoshio Hasegawa's WTA Scraper tool to obtain all Washington Trails Association (WTA) trip report data from 1998 to 2021 in csv format. The csv provided roughly 4,000 rows of data and contained route rating, rating count, report dates, report count, and trip/trails names columns that could be used to symbolize and classify the layer. I converted the csv to vector points using the Display XY Data tool and two new vector points layers: WTA_MONTHS and WTA_50. The WTA_50 layer contains all trips/trails that contain 50 or more trip ratings. This layer was symbolized using graduated sizes and colors with the Natural Jenks classification method. The WTA_MONTHS layer used all 3,906 rows of data with the intention of being able to temporally display this data in my web application. This was also an opportunity to implement Python into my project. I created a "Month" column to display the month of the trip report as text instead of a date format and needing to extract the month "REPORT_DAT" column in my WTA data. To do so, I used the Python expression displayed in Figure 2 below:

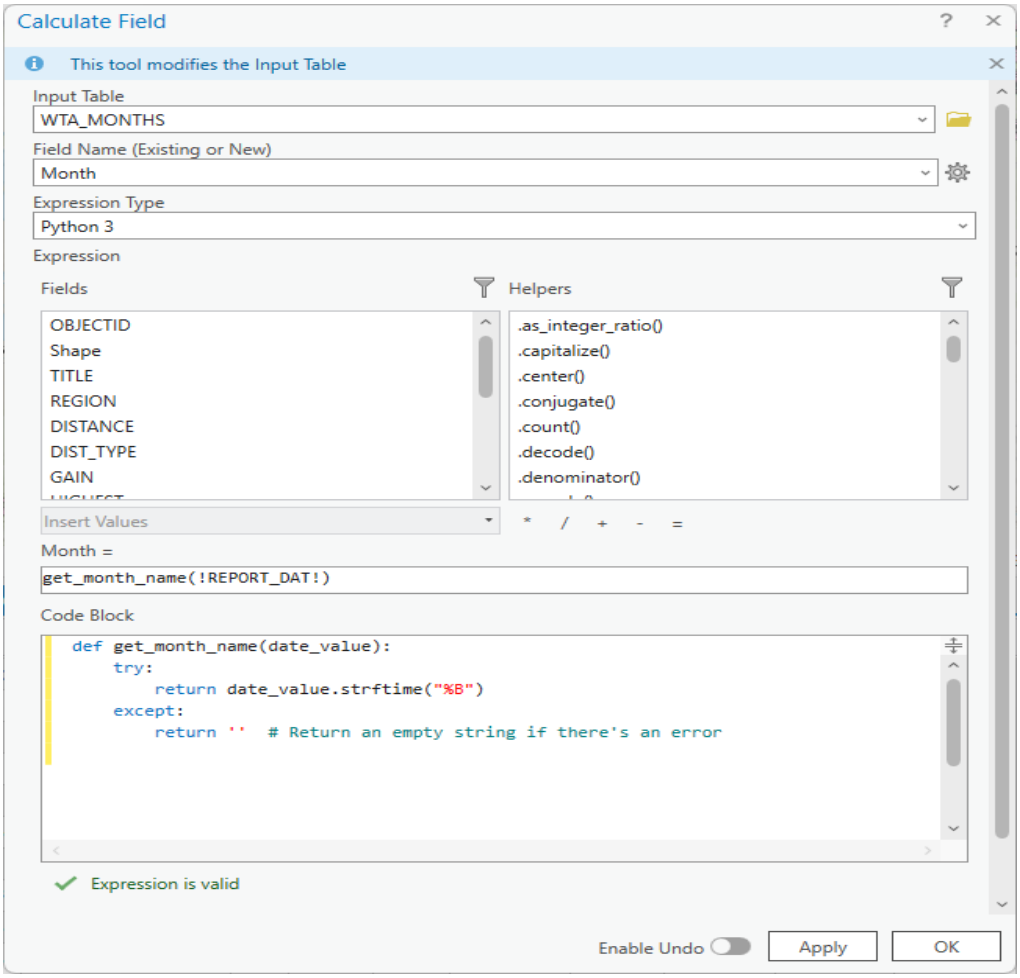

Figure 2. Extracting month values with Python in the Calculate Field tool.

The last piece of data processing involved creating a simplified sensitive habitat layer that combined all species' sensitive habitat layers (12 of them) into one new vector polygon. Each "event" was given a row in the attribute table after I used the Append tool to combine the layers into a new combined sensitive habitat layer. The columns remained the same with the "Start" and "End" columns being vital to future temporal visualization desires. The new layer was titled WILDLIFE_HAB_SIMP.

4.2 Managing Geospatial Data via ArcGIS Online

With the layers developed, I began the process of building my web application. First, I shared the clipped USFS & NPS trails, sensitive habitat, and NLCD layers to my University of Washington Tacoma Geospatial Technologies (hereinafter UWTGT) ArcGIS Online account in my "Content" section and make them available for public viewing so they could be seen in the web application. I also uploaded all layers as vector tiles to keep the symbology I created for each layer in ArcGIS Pro. From there, I created AGOL Web Scenes for each of the 7 selected species to display habitat-recreation overlaps. Sensitive habitat layers and the respective HCA layer for each species was used to visualize wildlife habitat, while a WTA Rating Count heat map layer and a 3D layer created from WTA_MONTHS were used to represent recreation overlap on wildlife habitat.

Essential to this project was my ability to represent sensitive wildlife habitat data temporally. After attempting numerous Python and Java scripts, I ended up with a much simpler solution to solve my time dilemma. Using the WILDLIFE_HAB_SIMP I created in ArcGIS Pro, I created an AGOL layer with a filter expression that leveraged the date formatted "Start" and "End" fields to set my desired time parameters. Sensitive habitat events are displayed monthly, meaning the start and end dates need to fall within the current month. The expression I used can be seen in Figure 3.

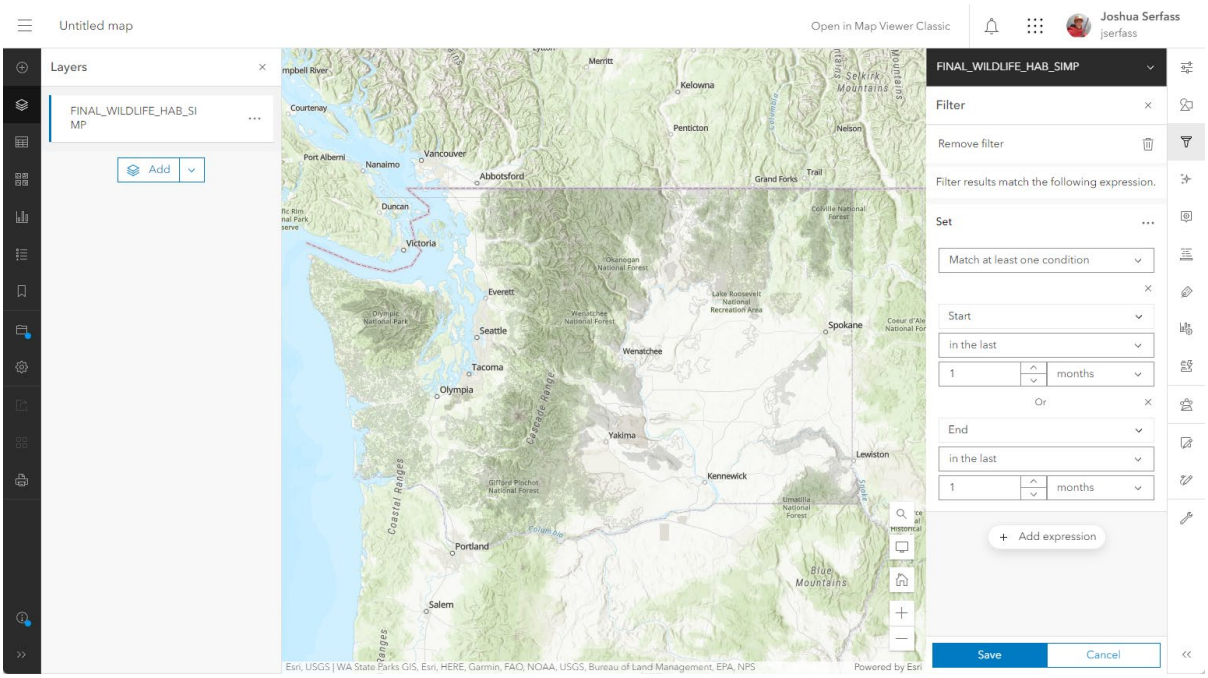

Figure 3. Expression used to display only habitat layers within the current month.

4.3 Tread Lightly Web Application Development

Like I mentioned previously, I decided to go with ArcGIS Experience Builder Developer Edition to construct my mobile-friendly web application. I downloaded Experience Builder from the ArcGIS Developers website and downloaded the 18.16.1 version of Node.js, which is the most compatible version for Experience Builder (EB). I installed the necessary dependencies via the command prompt, set up my OAuth 2.0 registered application through AGOL.

To begin designing my application, I explored the Experience Builder templates provided in the application's main menu. There were many templates containing features I wanted to implement in my project, but none of them seemed to encompass everything I wanted. The "Scenic" template came the closest though and had the layout I liked the most. It could be used as a starting point where I could keep what I wanted, get rid of what I didn't want, and bring in additional features using the EB widgets. The. I created "Pages" (as they are called in EB) for my main Backpacking Trip Planning Application, each of the 7 select species that spotlighted the sensitive species habitat web scenes I created in AGOL, and a timeline map. These pages are linked from images on the cover page of my *Tread Lightly* app. These links and images serve as the foundation of the app and can be scene in Figure 4. Greater detail pertaining to the application's functionality is discussed in the next section.

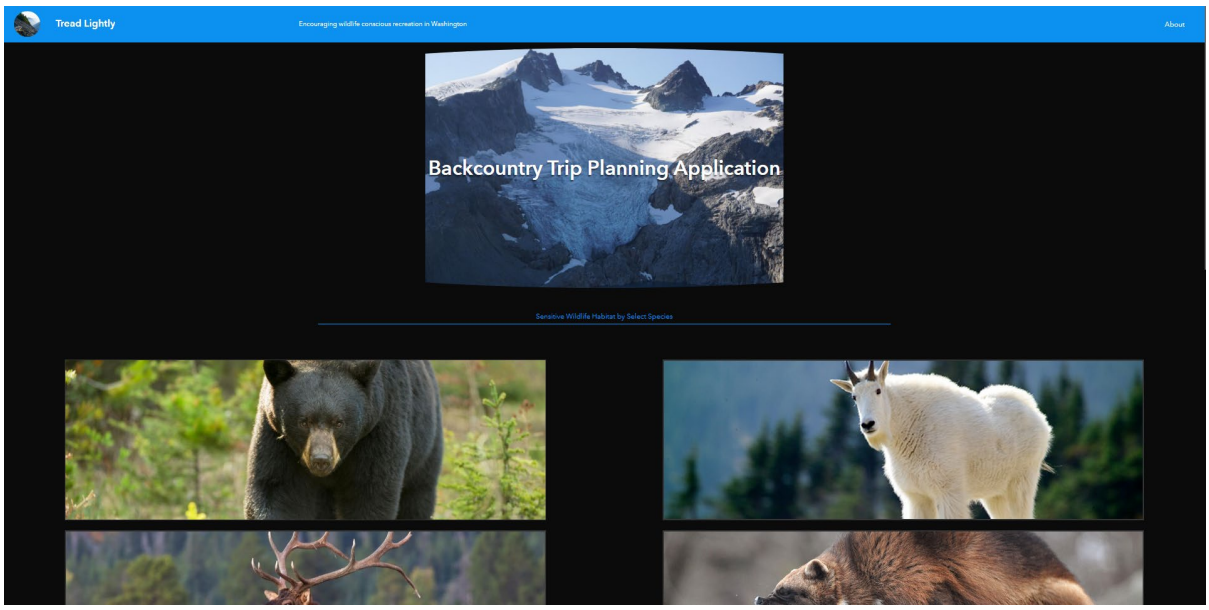

Figure 4. The top-most portion of the *Tread Lightly* web application.

5. Discussion

5.1 *Tread Lightly* Functionality

As already declared, application functionality was a big motivator in my decision to work with Experience Builder. Key to this project was the application's ability to provide a highly interactive user experience that is both educational and practical. Practicality and utility were especially important for the Backcountry Trip Planning Application or BTPA. The BTPA is a 3D Scene that enables users to plan for trips in Washington while being made aware of sensitive habitat types they may cross through on their adventures. US Forest Service and National Park Service administrative boundary layers and wilderness areas are displayed and labelled when the user opens the application, so the user gets an immediate sense of spatial awareness. Users can choose to see USFS & NPS trails or WTA trip report and trip review density layers (in case you're looking to avoid crowds) to aid their planning. Most

importantly, users will see seasonally sensitive wildlife habitat layers (symbolized by species and event) if the wildlife event (i.e., elk calving, black bear denning, etc) occurs in the month in which the app is being used. (It's worth noting that with this paper being completed in August, no sensitive habitat areas will be visualized because August is the only month without temporally sensitive habitat for the species of this project.) A look at the BTPA, with public lands data displayed, can be seen in Figure 5. All layers (in all application maps) can be toggled on or off and contain legends and pop ups for further user information.

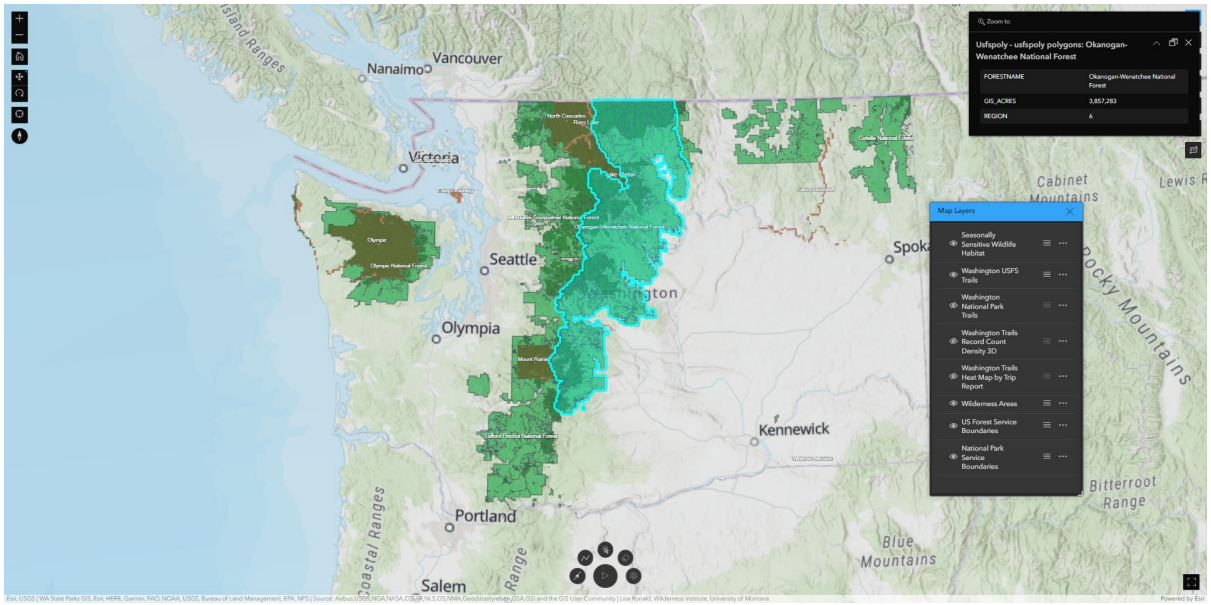

Figure 5. BTPA screen with pop up and legend displayed.

The BTPA really shines when the user hones into the 3D realm to trip plan. I included Add Data, Search, Elevation Profile, Draw, and Coordinates/Conversion widgets to provide optimal functionality. As a backcountry enthusiast, I find the Add Data and Elevation Profile widgets to be especially handy. Add Data allows me to add my own or my friends' routes to the map to see how they will interact with sensitive habitat. Moreover, the Elevation Profile widget breaks down the mileage and elevation gain statistics, while visualizing them in a graph and providing options to reverse direction or export the drawn elevation profile route. Figure 6 below shows the elevation profile results for a route drawn from the end of the trail on Jack Mountain in North Cascades National Park.

Figure 6. A route up Jack Mountain as displayed via the Elevation Profile widget.

Similar functionality is found in each of the sensitive habitat scenes for the highlighted species. Users can add data, draw routes, search, get coordinates, and change the basemap for each of the 7 scenes. However, unlike the BTPA, the sensitive habitat scenes do not display the sensitive habitats temporally. Rather, those layers can be turned on or off at any time, and unlike the combined sensitive habitat layer used in the BTPA, these layers are event-specific and employ symbology from the NLCD layer to effectively symbolize the different sensitive habitat types. In addition to proper habitat symbology, another advantage of being able to turn the sensitive habitat layers on or off for users is that they can see the intersection of potential routes with sensitive habitat at any time of the year, not just the current month. On top of the aforementioned functionality, the species sensitive habitat scenes contain interactive graphs breaking down approximate habitat by acreage and percentages, and facts about how each species is affected by recreation of varying types at different times of the year. Figure 7 shows the Bighorn Sheep Sensitive Habitat page homed in on rutting habitat near just outside of Wenatchee, Washington.

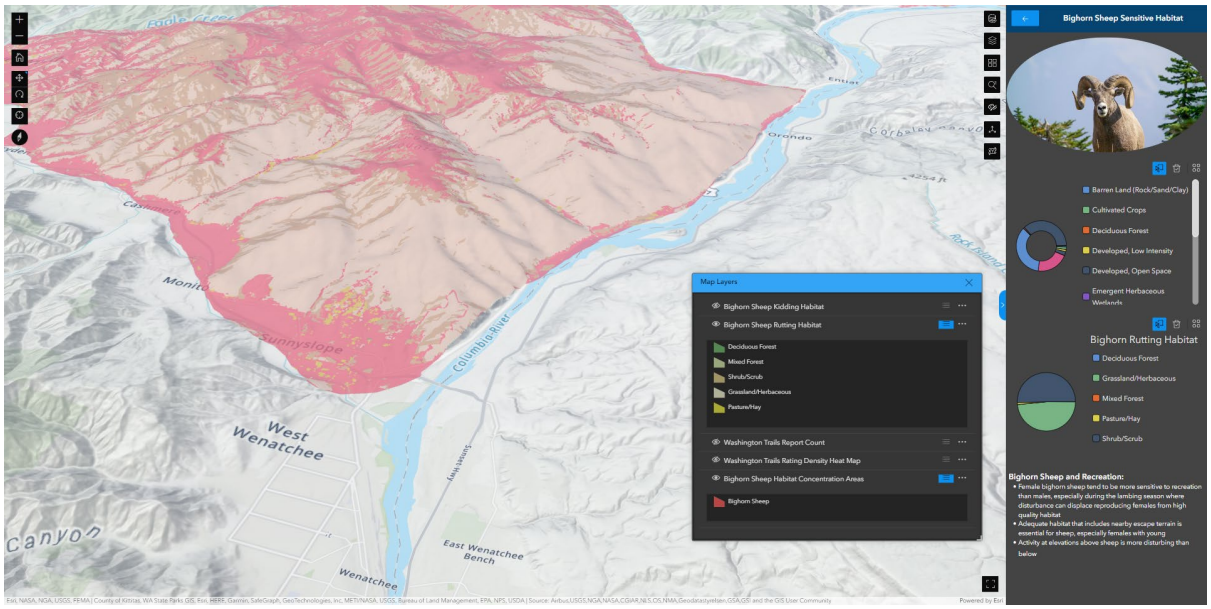

Figure 7. Bighorn Sheep Rutting Habitat near Wenatchee, WA.

Along with trip planning and education, I wanted user inclusiveness to be a focus for *Tread Lightly*. To promote inclusivity in wildlife conservation for backcountry enthusiasts, I developed a survey to enable users to report wildlife sightings while out on their adventures. As a bonus, this survey can be an avenue for continued recreational data implementation and visualization in the future. Naturally, with Experience Builder being the platform for *Tread Lightly*, I chose to go the ESRI route for my survey as well. I completed the survey in Survey 123 and linked to the survey from the front page of the application. Data turned in via the survey is stored on AGOL and can be exported to csv for future integration into the web application. The Wildlife Observation survey contains 9 questions/fields as follows:

1. Location of Sighting (mandatory) – Created via a click on the map or entering coordinates.
2. Species Observed (mandatory) - The common or scientific name of the species seen in the wild, entered in a text box.
3. Approximate Number of Individuals Observed (mandatory) - Number of species observed, entered in a text box.
4. Date of Sighting (mandatory) – Entered via date fields.
5. Time of Sighting (optional) – Entered via time box with hour, minutes, and am/pm options.
6. Photo of Wildlife (optional) – Upload an image from file or phone camera.
7. Your Name (optional) – Entered in a text box.
8. Your Contact Information (optional) - Entered in a text box.
9. Additional Notes? (optional) - Notes about visitation in the area, weather, wildlife behavior, etc. Entered in a text box.

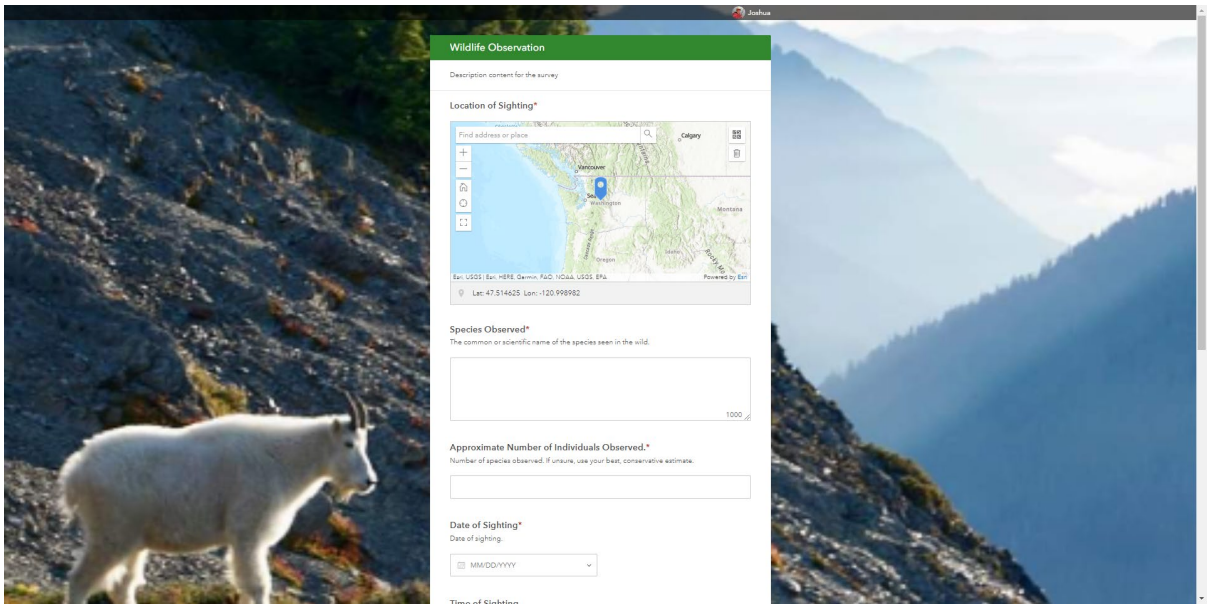

Figure 8. A look at the Wildlife Observation survey.

5.2 Wildlife-Recreation Overlap

Looking at the Washington Trails Association Ratings Count and Trip Report Count layers paints a clear, and perhaps expected picture about the overlap between wildlife and recreation in Washington. Not surprisingly, the WTA data shows that recreation density is greatest West of the Cascade Mountains and at its peak in easily accessible areas near the Puget Sound. The further one gets from Puget Sound, the less the recreation density. For some species, like the Canada Lynx or Bighorn Sheep, that means relatively low overlap between recreational usage and sensitive habitat areas. This is particularly important for threatened or endangered species like the Canada Lynx. On the flip side, species with large habitat ranges like elk, black bears, or deer see substantial recreational overlap in sensitive habitat areas. This can lead to conflict and wildlife stress – particularly during wintering and birthing seasons. Figure 9 shows a case of a species with a large habitat range, the black bear, containing areas with heavy recreational usage. The map shows where the top 50 WTA trip report locations overlap with potential black bear denning habitat in the Mount Baker Snoqualmie National Forest.

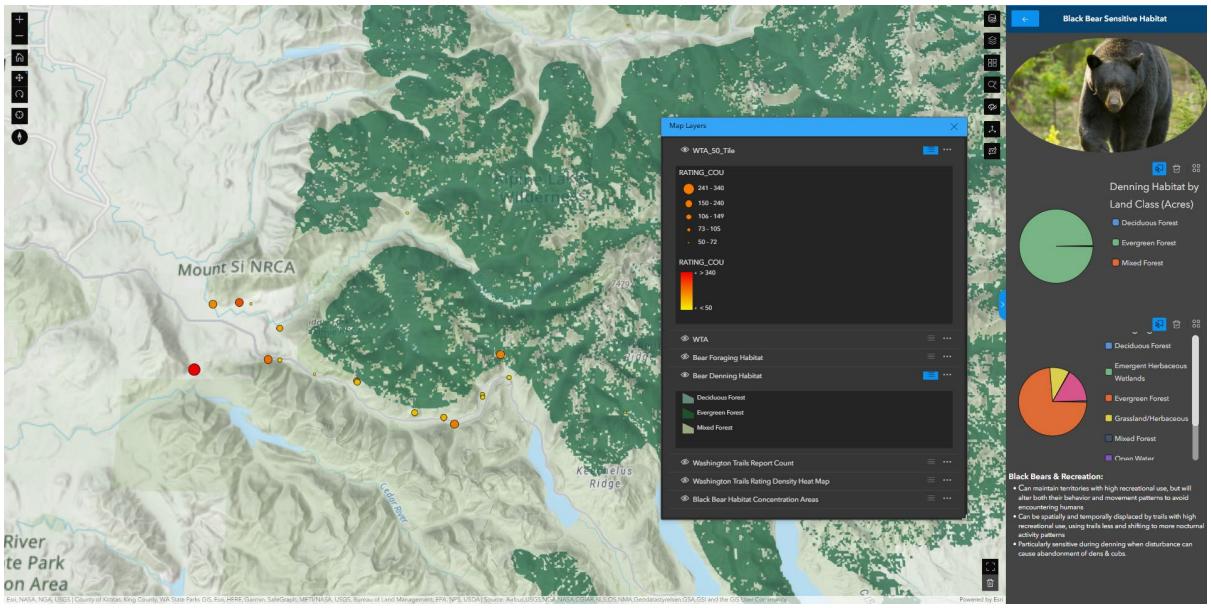

Figure 9. Black bear denning habitat and high use recreation in the MBSNF.

6. Conclusion

6.1 Going Forward

I knew this project was ambitious when I first envisioned it, and while I have completed most everything I intended to, I have discovered additional items along the way that I would like to expand upon in the future. A list of these items is as follows:

- Implement collected survey data to create additional visualizations whether it is maps, charts, or graphs.
- Continue to refine the web application's appearance with an eye on fine-tuning details, such as correcting pop-up presentation.
- Complete a timeline map overlaying trip reports by month, on top of that month's respective sensitive habitat areas, throughout the course of available data from 1998 to present.
- Improve layer loading efficiency/speed.
- Integrate migration corridors into the sensitive habitat pages.

- Add additional recreational usage sources. (I ran into some issues scraping data during the completion of this project.)
- Add additional species of focus to the project… Perhaps this can be accomplished with the help of my survey?

This project kept me busy throughout the past several months and there are countless ways for it to continue to keep me occupied and engaged.

6.2 Final Remarks

Although there are numerous human benefits driving the current outdoor recreation boom, there is unease in the conservation movement about the impacts this boom has for wildlife both currently and into the future. Despite the biological and ecological concerns of the scientific community, most outdoor visitors underestimate their own impact, either through a lack of awareness or flat-out denial, and often react defensively to criticism, instinctively blaming other types of recreation, never their own (MacDonald, 2015). Still, connections with nature are deemed vital to garnering support for the conservation and preservation of public lands in the United States (Zaradic, et al., 2009).

With that last statement in mind, a major goal when setting out on this project was to create a mobile-friendly web application that not only provides utility for backcountry enthusiasts in getting outside and exploring in a wildlife conscious manner, but also makes people in the outdoors community feel like they can play a part in wildlife conservation. Like most things, there is a balance to be found here, and I tried to hone in on that balance throughout this process. *Tread Lightly* balances responsibility with play and attempts to serve the desires of both the conservation and recreation communities while assisting in the mitigation of potential recreation impacts for wildlife on public lands in Washington State. The facts are the facts, but in order to get the greater public on the conservation train, it's vital to present the facts in an easily understandable manner while making the educational process fun! I hope, and believe, that this project accomplished that goal.

7. References

Balk, G. “The decade in demographics: Top 5 changes in the Seattle Area”. Seattle Times. Dec. 30, 2019.

Bighorn Sheep. Washington Department of Fish & Wildlife. (n.d.-a). https://wdfw.wa.gov/species-habitats/species/ovis-canadensis#:~:text=The%20bighorn%20breeding%20season%2C%20or,head%2Dto%2Dhead%20combat

Black Bear. Washington Department of Fish & Wildlife. (n.d.-b). https://wdfw.wa.gov/species-habitats/species/ursus-americanus#desc-range

Brogden, M. J., & Greenberg, J. B. (2020). The fight for the west: A political ecology of land-use conflicts in Arizona. Political Ecology Across Spaces, Scales, and Social Groups, 41–60. https://doi.org/10.36019/9780813542546-004

Burns, R. C., Popham, A. R., & Smaldone, D. (2018). Examining Satisfaction and Crowding in a Remote, Low Use Wilderness Setting: The Wenaha Wild and Scenic River Case Study. Int. J. Wilderness, 24(3).

Canada lynx. Washington Department of Fish & Wildlife. (n.d.). https://wdfw.wa.gov/species-habitats/species/lynx-canadensis#desc-range

Cole, David N.; Wright, Vita. (2003). Wilderness visitors and recreation impacts: baseline data available for twentieth century conditions. Gen. Tech. Rep. RMRS-GTR-117. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 52 pp. https://doi.org/10.2737/rmrs-gtr-117

Dertien, J. S., Larson, C. L., & Reed, S. E. (2021). Recreation effects on wildlife: A review of potential quantitative thresholds. Nature Conservation, 44, 51–68. https://doi.org/10.3897/natureconservation.44.63270

Elk. Washington Department of Fish & Wildlife. (n.d.-c). https://wdfw.wa.gov/species-habitats/species/cervus-canadensis

Environmental Protection Agency. (2022). Biden-Harris Administration to Help Rural Communities Grow Outdoor Recreation Economy. Retrieved February 11, 2023, from https://www.epa.gov/smartgrowth/recreation-economy-rural-communities 0

Gaines, W. L., Singleton, P. H., & Ross, R. C. (2003). Assessing the cumulative effects of linear recreation routes on wildlife habitats on the Okanogan and Wenatchee National Forests. Gen. Tech. Rep. PNW-GTR-586. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 79 p, 586. 10.2737/pnw-gtr-586

Hasegawa, Y. (n.d.). Yoshiohasegawa/WTA-scraper: A web scraper used to access all the hike data from Washington Trails Association (WTA). Washington Trails Association Web Scraper. https://github.com/yoshiohasegawa/wta-scraper

Karsch, R. C., Cain, J. W., Rominger, E. M., & Goldstein, E. J. (2016). Desert Bighorn Sheep Lambing Habitat: Parturition, nursery, and predation sites. The Journal of Wildlife Management, 80(6), 1069–1080. https://doi.org/10.1002/jwmg.21092

Krakoff, S. (2003). Mountains without handrails ... wilderness without cellphones. The Harvard Environmental Law Review : HELR, 27(2), 417–417.

Larson, C. L., Reed, S. E., Merenlender, A. M., & Crooks, K. R. (2016). Effects of Recreation on Animals Revealed as Widespread through a Global Systematic Review. PloS One, 11(12), e0167259–e0167259. https://doi.org/10.1371/journal.pone.0167259

Living with wildlife: Deer. Washington Department of Fish & Wildlife. (n.d.-d). https://wdfw.wa.gov/species-habitats/living/species-facts/deer#

Lowery, R. (2022, September 14). Daines, King introduce bipartisan bill to address increased visitation on public lands and support partnerships with Montana Gateway Communities. Senator Steve Daines. Retrieved February 11, 2023, from https://www.daines.senate.gov/2022/02/02/daines-king-introduce-bipartisan-bill-to-address-increased-visitation-on-public-lands-and-support-partnerships-with-montana-gateway-communities/

MacDonald, J. (2015, March 6). Outdoor Recreation Can Impact Wildlife . JSTOR DAILY. Retrieved February 20, 2023, from https://daily.jstor.org/outdoor-recreation-impacts-wildlife/

Machowicz, A., Vanbianchi, C., & Windell, R. (2022). Recreation and Wildlife in Washington: Considerations for Conservation (pp. 1–115). Winthrop, WA: Home Range Wildlife Research https://conservationnw.org/wp-content/uploads/2022/09/Recreation-and-wildlife-in-Washington-Considerations-for-conservation_FINALreduced.pdf

Mojica, J., Fletcher, A., 2020. Economic Analysis of Outdoor Recreation in Washington State, 2020 Update. Earth Economics. Tacoma, WA.

Mountain Goat. Washington Department of Fish & Wildlife. (n.d.-c). https://wdfw.wa.gov/species-habitats/species/oreamnos-americanus#:~:text=The%20mountain%20goat%20breeding%20season,mid%2DNovember%20through%20early%20December

Nelson, Libby & Bailey, David. (2021). The "Recreation Boom" on Public Lands in Western Washington: Impacts to Wildlife and Implications for Treaty Tribes. 10.13140/RG.2.2.12224.25602.

NWNews | By Tom Banse. (2021, May 28). No let up expected this summer in crowding at parks and Trailheads. Northwest News Network. Retrieved January 24, 2023, from https://www.nwnewsnetwork.org/lifestyle-leisure-and-sport/2021-05-27/no-letup-expected-this-summer-in-crowding-at-parks-and-trailheads

Office of Financial Management, State Population Forecast: 2020–2050 (2022). Olympia,, WA; Office of Financial Management, Forecasting Division.

Olson, L. E., Squires, J. R., Roberts, E. K., Miller, A. D., Ivan, J. S., & Hebblewhite, M. (2017). Modeling large-scale winter recreation terrain selection with implications for recreation management and wildlife. Applied Geography (Sevenoaks), 86, 66–91. https://doi.org/10.1016/j.apgeog.2017.06.023

Parker , B. (2022, January 31). Trail based recreation and its impacts on wildlife. Backcountry Hunters and Anglers. Retrieved February 20, 2023, from https://www.backcountryhunters.org/trail_based_recreation_and_its_impacts_on_wildlife

Schwarzenegger, A., Chrisman, M., & Coleman, R. (2005). The health and social benefits of recreation: An element of the California outdoor recreation planning program. California State Parks, Sacramento, CA. https://www.parks.ca.gov/pages/795/files/benefits%20final%20online%20v6-1-05.pdf

Sportsman, N. (2017, January 20). Update on Washington Winter Range Conditions for deer, elk. Medium. https://medium.com/@NSportsmanMag/update-on-washington-winter-range-conditions-for-deer-elk-6453a659a4aa

Wolverine. Washington Department of Fish & Wildlife. (n.d.-c). https://wdfw.wa.gov/species-habitats/species/gulo-gulo-luscus#desc-range

World Population Review. (n.d.). Fastest Growing States 2023. Fastest growing states 2023. Retrieved February 20, 2023, from https://worldpopulationreview.com/state-rankings/fastest-growing-states

Zaradic, P. A., Pergams, O. R., & Kareiva, P. (2009). The impact of nature experience on willingness to support conservation. PLoS ONE, 4(10). https://doi.org/10.1371/journal.pone.0007367

Zhang, H., van Berkel, D., Howe, P. D., Miller, Z. D., & Smith, J. W. (2021). Using social media to measure and map visitation to public lands in Utah. Applied Geography (Sevenoaks), 128, 102389–. https://doi.org/10.1016/j.apgeog.2021.102389