Department of Defense

Legacy Resource Management Program

PROJECT 08-346

Document Status: Final

Important Bat Habitat Model (v2) Evaluation

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January 2008

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INTRODUCTION

A total of 19 bat species are known to occur in Utah; 6 of which are considered Species of Concern (Oliver et al. 2008). Unfortunately, very little information is known about the distribution or population status of bats in the state (Oliver 2000). Prior to this project, bat inventory data for Utah was scattered within private, state, and federal holdings and were not collectively available for resource managers. This lack of information presents difficultly in identification and hence ways to address statewide management issues related to the conservation of Utah's bats. The Department of Defense (DoD), with five installations whose management authority extends over 1.8 million acres, deemed it crucial to identify distribution and frequency of occurrence to prevent encroachment and listing issues related to the lack of conservation management of bat species in Utah. In order to address bat monitoring shortfalls, we produced an Important Bat Habitat Model (BHM).

The BHM, produced for the Legacy I project (Legacy 07-346) provided an estimate of the value of habitat based on the interaction of wetland distribution, vegetative land cover, bedrock geology, elevation, and topographic relief. The model provided an initial step in identifying and monitoring high value bat habitat. The next stage in the model development is an evaluation and comparison of other habitat based predictive models with the actual observed bat distribution patterns (gleaned from Legacy II 08-346 data analysis work).

In order to evaluate this model, we used the data concentrated by Biologists at Dugway Proving Ground (DPG) in cooperation with the Utah Division of Wildlife Resources (UDWR) and members of the Utah Bat Conservation Cooperative (UBCC), an organization comprised of members from 14 land and resource management agencies. DPG and its partners received DoD funding from the Legacy Resource Management Program to consolidate and organize all existing

bat data in Utah into a centralized geodatabase (BATBASE). To date, the BATBASE data set is the result of 16 types of contributors, over 150 observers, 13,876 events (records), and 28,629 individual bats. These data provide a location and presence for Utah's 19 bat species and the number of individuals throughout the state. The occurrence of species across the same scales used to create the BHM provides an estimate of the BHM's accuracy.

METHODS

The BHM identifies important bat habitat throughout Utah and was constructed following the methods of Keinath (2004). To start, all geographically referenced electronic data delineating six key resources for bats were collected and compiled for analysis in a Geographic Information System (GIS). As identified by Keinath (2004), important key landscape level resources for bats include wetland distribution, vegetative land cover, bedrock geology, elevation, and topographic relief (slope and aspect). After acquisition, raster (grid) coverages were generated from each key resource layer to facilitate the scoring and weighting of each 100 m x 100 m cell. An algorithm was used to compile scores and weights into a final value of habitat suitability for bats within every 100 m cell in Utah. The higher the suitability value of the cell, the more likely it contains habitat characteristics that support a high diversity and density of bat species. This method has already been used successfully to develop an inventory of bat species in the Greater Yellowstone Region (Keinath 2001, 2004). Project outputs include an ArcGIS shapefile ranking the suitability of bat habitat in Utah (Fig. 1). Figure 2 identifies habitat suitability on DoD lands in Utah predicted by the BHM.

The BATBASE data set was analyzed on three ecological scales: ecoregion (World Wildlife Fund Global Ecoregions), physiographic provinces (Utah Geological Survey) and land-cover classification (SW Re-GAP). This allowed for an analysis of bat use and distribution at varying scales to address specific needs. The ecoregion ecological scale provided us with a broad view of ecological associations while the physiographic provinces allowed for an evaluation of broad scale land-form relationships. Land cover classification was evaluated with SW Re-GAP data at a 30 m pixel scale for interpretation of species and environmental associations. SW Re-GAP data is error prone and thus was assumed to be nested within a framework of similar cover

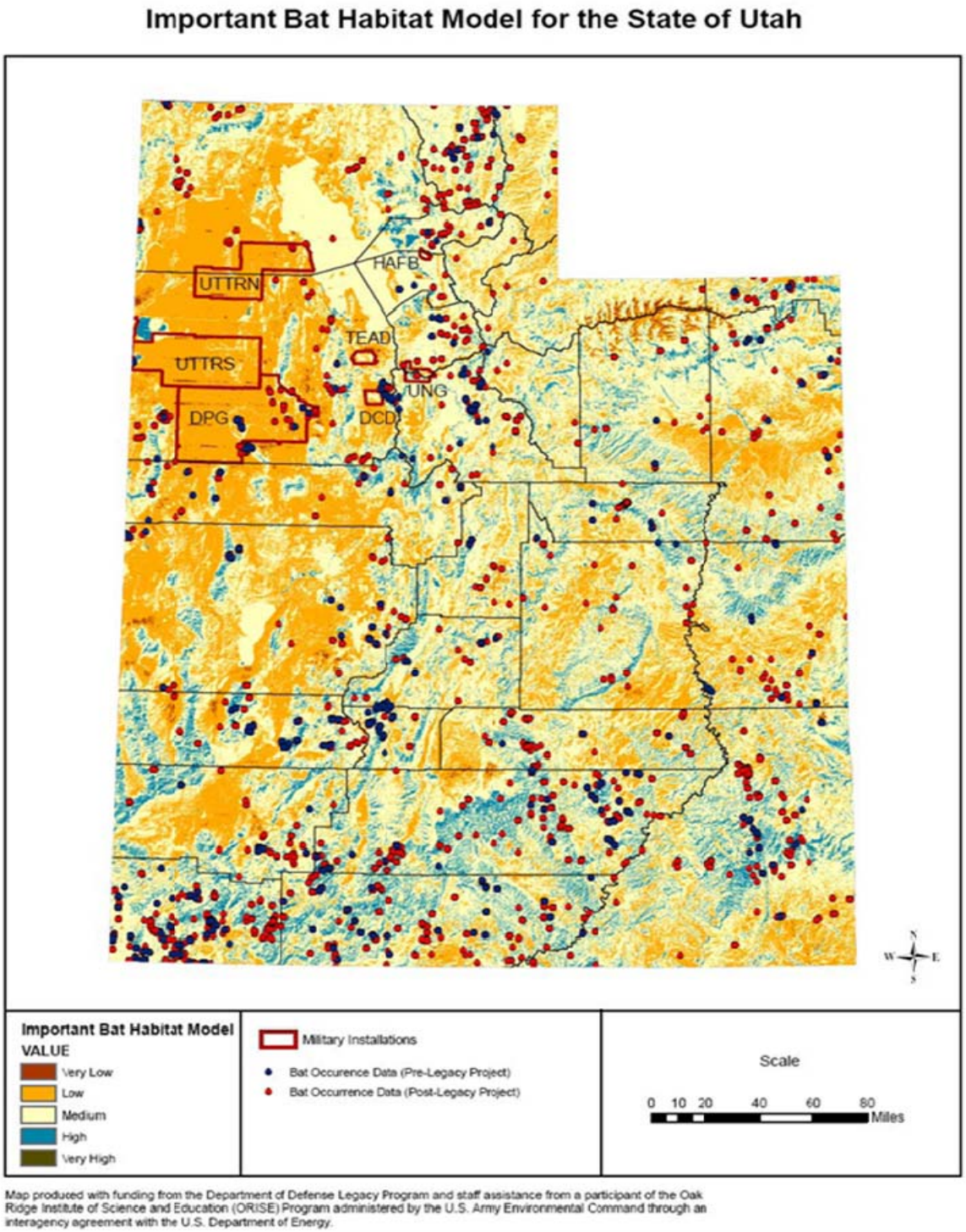

Figure 1. Important Bat Habitat Model for the State of Utah and bat occurrence data prior to the BATBASE data analysis.

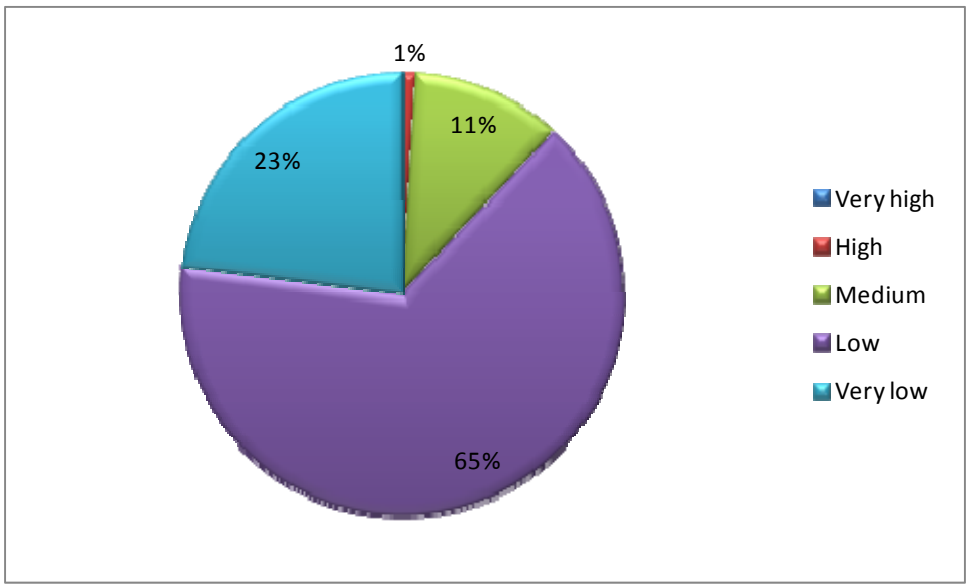

Figure 2. Department of Defense lands in Utah across 5 habitat value classes.

types and analysis at this scale provides only an indication of habitat associations. These three ecological scales provided an estimate of species and habitat associations in habitat types.

We also analyzed all data on three managerial scales: landowner type, UDWR region, and county. The landowner type analysis provided species occurrence under categories of management. UDWR's regions were used to establish a listing of species occurrences and abundance. By analyzing these data on a county managerial scale, we obtained a further assessment by management category. We used a frequency analysis (PROC FREQ in SAS) comparing the number of events by species in each of the 6 management scales in SAS®. This analysis serves as a descriptive data layout providing an overview of the entire data set (pers comm. S. Durham) with such a diverse (temporal, spatial, and methodological) data set. Additional results from the analysis of bat data in Utah gathered during Legacy I (#07-346) (not related specifically to the BHM), can be found in the Status of Utah Bats report, a separate deliverable to the Legacy Resources Management Program for this project (#08-346).

To compare the BHM with the BATBASE data output, we evaluated the value of the BHM habitat with the coarse scale bat diversity and density across ecoregion, land cover, and landowner. The initial value of habitat was scaled as very high, medium, low, very low. The diversity and density of bats was also scaled as very high, high, medium, low and very low with the use of Shannon-Weiner diversity index and density of individual bats across species.

For further evaluation, we compared a bat habitat model that predates our own by 10 years. The Utah GAP Analysis (GAP) predicted bat habitat in Utah by species, based on the 1995 Utah GAP. The quality of habitat and the location of habitat can be viewed as an overlap with bat species distribution and activity density created with the BATBASE data set. We evaluated the overlap between the Utah GAP Analysis Predicted Habitat Quality across four habitat values; critical, high, substantial and limited. By evaluating this historical GAP Model alongside our own BHM we gain a better understanding of the accuracy of our model. The side by side comparison of the BHM and the GAP using the BATBASE data set provided a measure of accuracy for both.

RESULTS

The BHM produced a five step scale of habitat suitability with the highest value habitat scored as a five and lowest as a one. The area of each of these habitat values differed (Fig. 3). The population density within these habitat types also varied. The highest survey effort was in medium value habitats that cover the second highest percentage of land in the state and on 11% of DoD lands. The low value habitat type had a lower survey effort than expected by the area cover by this type. This low value habitat type describes over 50% of Utah's land area and 65% of the land cover on DoD lands in the state (Fig.2). The very low habitat value is also under surveyed, consisting of 15% of Utah's land cover and less than 10% of the total survey effort. Very low value habitat makes up 23% of DoD land cover. High value habitats accounts for 1% of total land cover (none on DoD land) yet nearly 10% of the total survey effort.

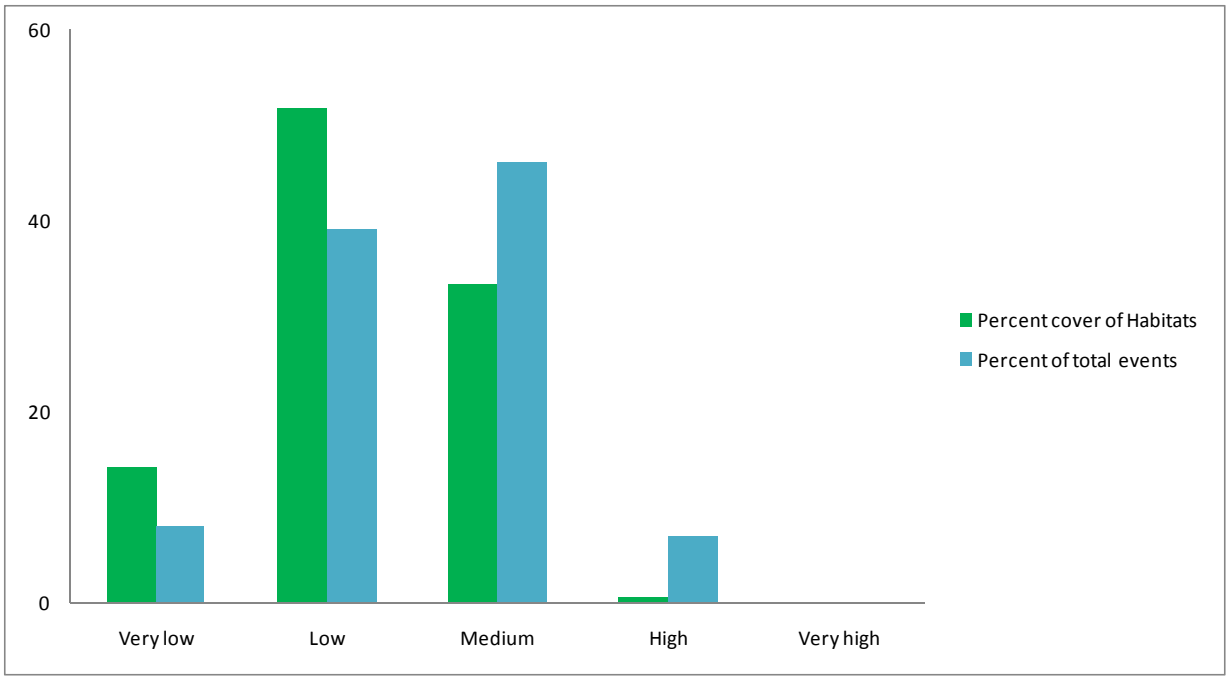

Figure 3. Percent of Utah landcover (Y axis) and percentage of total events (BATBASE) within each of the BHM habitat value classes (X axis).

Utah's five ecoregions vary across diversity and density with the habitat value index. Ten of the 16 high value land cover types are located exclusively in the Wasatch and Uinta montane forest ecosystem (Table 1). While the Wasatch and Uinta montane forests have the third highest diversity index value it has the highest density of individual bats (Figs. 4 and 5). The high diversity and density of bats in the Wasatch and Uinta montane forest is a result of the high quality of foraging and roosting habitat found in this ecoregion. The Colorado Plateau shrublands had the highest diversity score and the second highest density of bat individuals. The Colorado Plateau shrublands have one exclusive high value land cover, and one exclusive high value landform category (Tables 1 and 2). The Great Basin Shrub Steppe ecoregion had the second highest diversity score and the third highest bat density. One-eighth of the high value land cover and 1/3 of high value landforms are exclusive to Great Basin shrub steppe (Tables 1 and 2). The Mojave Desert ecoregion had a diversity score similar to the two previous ecoregions but a considerably lower population density. Three of the high value land cover types and two of the high value landforms are exclusive to the Mojave Desert. The high diversity and low population density are likely related to the long distance to water sources. The Wyoming shrub steppe had the lowest diversity and population density and has no exclusive high value land cover and landform types.

The value of habitats varied across land cover types as did the diversity and density of bat populations. The 16 high value land cover types as estimated by the BHM (Table 1) did not always support the highest diversity and density of bat populations as seen from the BATBASE analysis. The high value land cover types and high diversity and density of bat activity did not overlap completely, however, they showed similar trends in vegetation selection for riparian, montane and broad leaf plant communities (Tables 1 and 3). Differences were apparent however

in several vegetation types. The BHM valued invasive perennial grasslands, shrublands, and tundra vegetation as low value however; BATBASE diversity and density data do not support the BHM for these habitat types (Table 3). The BHM also underestimated the value of saltbrush, blackbrush, and sand shrublands. The value of emergent marsh was also underestimated. In whole the BHM predicted high bat density and diversity with moderate fidelity.

Table 1. High value land cover types as estimated by the BHM.

High value land cover
Rocky Mountain Aspen **Forest and Woodland**
Rocky Mountain Subalpine Dry-Mesic **Spruce-Fir Forest and Woodland**
Rocky Mountain Subalpine Mesic **Spruce-Fir Forest and Woodland**
Rocky Mountain **Lodgepole Pine Forest**
Rocky Mountain Montane Dry-Mesic **Mixed Conifer Forest and Woodland**
Rocky Mountain Montane Mesic **Mixed Conifer Forest and Woodland**
Rocky Mountain **Ponderosa Pine Woodland**
Colorado Plateau **Pinyon-Juniper Woodland**
Great Basin **Pinyon-Juniper Woodland**
Inter-Mountain West **Aspen-Mixed Conifer Forest** and Woodland Complex
Rocky Mountain **Subalpine-Montane Riparian Woodland**
Rocky Mountain **Lower Montane Riparian Woodland and Shrubland**
North American Warm Desert **Lower Montane Riparian Woodland and Shrubland**
North American Warm Desert **Riparian Woodland and Shrubland**
North American Warm Desert **Riparian Mesquite Bosque**
Great Basin **Foothill and Lower Montane Riparian Woodland and Shrubland**

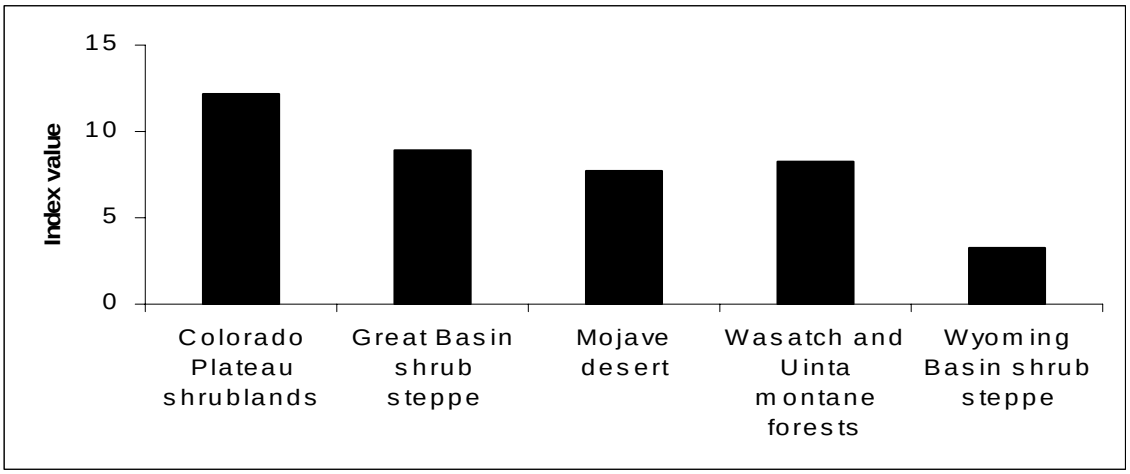

Figure 4. Shannon-Weiner diversity indices, based on the diversity and evenness of species across ecoregions.

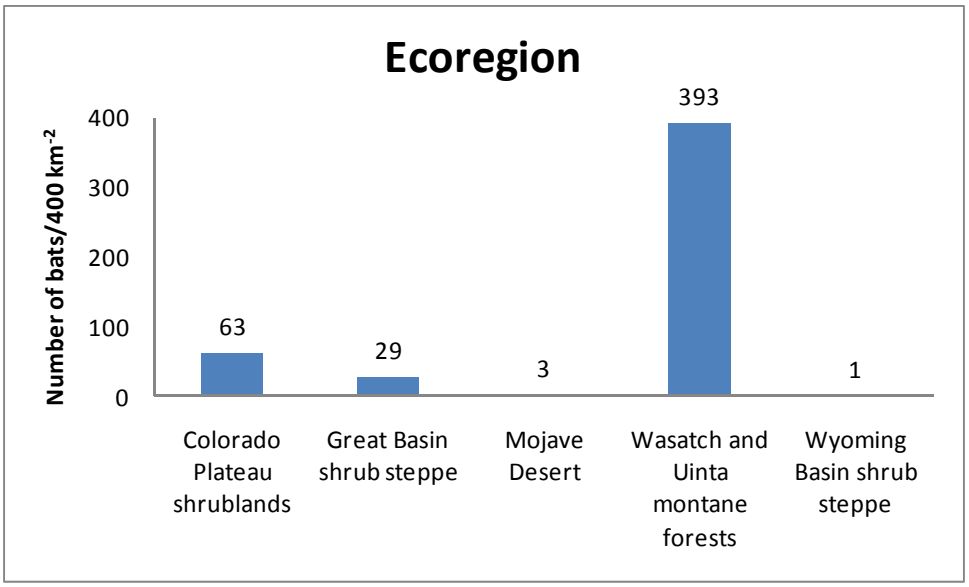

Figure 5. Bat individual density across Utah's 5 ecoregions from BATBASE data.

Table 2. High value landform types as estimated by the BHM.

High value landforms
Rocky Mountain **Cliff and Canyon**
Inter-Mountain Basins **Cliff and Canyon**
Colorado Plateau **Mixed Bedrock Canyon and Tableland**
Inter-Mountain Basins **Volcanic Rock and Cinder Land**
North American Warm Desert **Bedrock Cliff and Outcrop**
North American Warm Desert **Volcanic Rockland**

Table 3. Predicted high value bat habitat based on the BATBASE density and diversity of bats observed within.

High bat diversity and density land cover type
Invasive Perennial Grassland
Recently Chained Pinyon-Juniper Areas
Inter-Mountain West **Aspen-Mixed Conifer Forest** and Woodland Complex
Inter-Mountain Basins Mat **Saltbush Shrubland**
Rocky Mountain **Gambel Oak-Mixed Montane Shrubland**
Rocky Mountain **Lower Montane-Foothill Shrubland**
Great Basin **Semi-Desert Chaparral**
Colorado Plateau **Blackbrush-Mormon-tea Shrubland**
Southern Colorado Plateau **Sand Shrubland**
Rocky Mountain **Dry Tundra**
Southern Rocky Mountain **Montane-Subalpine Grassland**
Rocky Mountain **Subalpine-Montane Riparian Shrubland**
North American Arid West **Emergent Marsh**

The value of habitat varied across landowner as shown by density (Fig.6). The BHM value index predicted that DoD lands would be dominated primarily by low value habitat types, however, DoD lands had the second highest density and the third highest diversity of bats across landowner types. This difference in the model and the BATBASE density and diversity data is the result of the underestimation of the value of some land cover types that are dominant on DoD

lands. The categorization of invasive perennial grasslands, salt desert, blackbrush shrublands, and sand shrublands, as well as gambel oak woodlands as low or medium value habitats is likely the cause of these differences. Density and diversity indices indicate that these habitats are of high value rather than the initial low and medium value assigned with the original model. The highest value habitats are abundant on National Park Service (NPS) lands and this accounted for the high diversity and density of bats on this landowner type. U.S. Forest Service (USFS) and U.S. Fish and Wildlife Service lands (USFWS) also have a high proportion of high value habitats and high density and diversity of bat populations (Figs. 6 and 7). Bureau of Land Management (BLM) lands have a low density of bat activity but a high diversity value. This is the result of the large area of coverage by this land owner type and the associated diversity of land cover types.

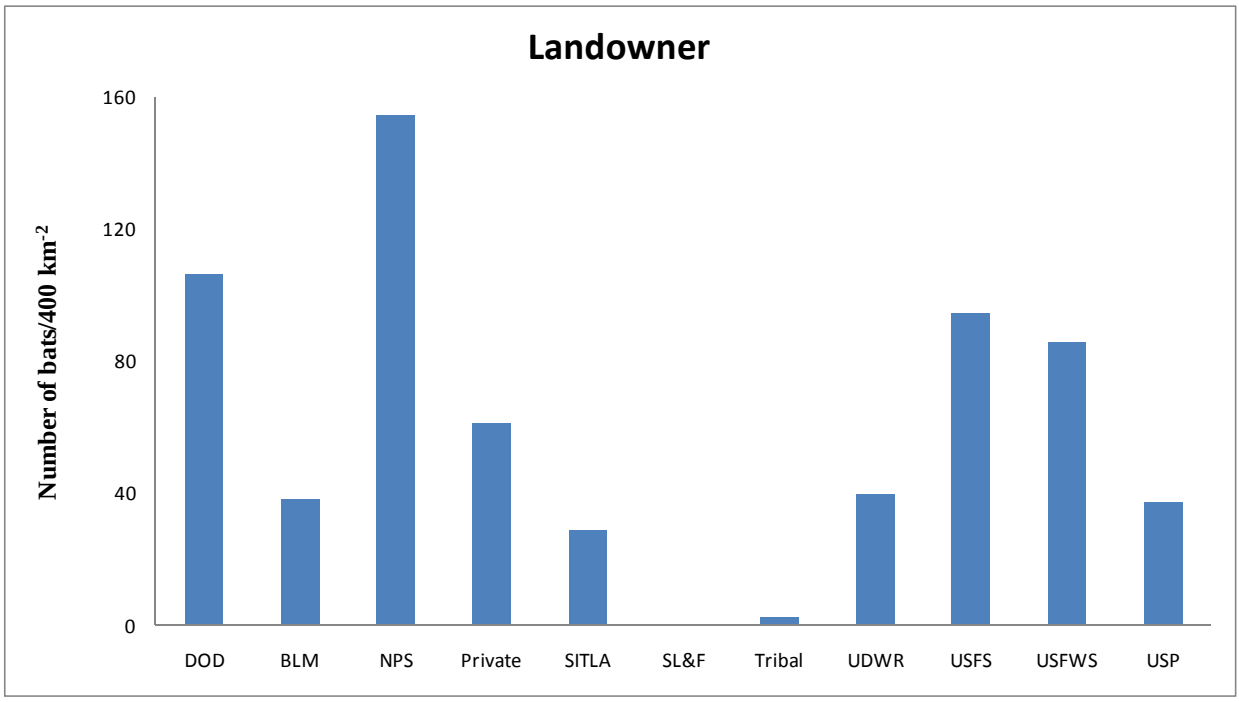

Figure 6. Density of bat individuals on 11 landowner types; Department of Defense (DoD), Bureau of Land Management (BLM), National Park Service (NPS), Private lands, State Institutional Trust Lands (SITLA), State sovereign lands (SL&F), Tribal lands, Utah Division of Wildlife Resources (UDWR), U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS) and Utah State Park lands (USP).

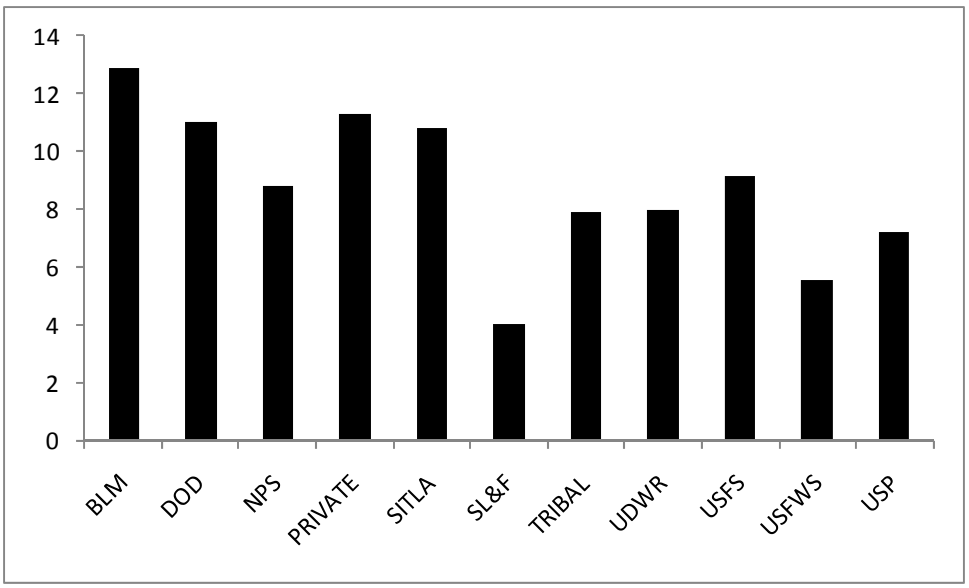

Figure 7. Diversity value calculated with the Shannon-Weiner diversity index across 11 landowner types. Department of Defense (DoD), Bureau of Land Management (BLM), National Park Service (NPS), Private lands, State Institutional Trust Lands (SITLA), State sovereign lands (SL&F), Tribal lands, Utah Division of Wildlife Resources (UDWR), U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS) and Utah State Park lands (USP).

The GAP model project created habitat models for Utah's bat species, which varied from the density of bat capture events observed in the BATBASE data set. The Townsends big-eared bat density differed form that predicted in the GAP (Fig. 8). The BHM predicted high value habitat in the southwestern and eastern portions of Utah. Event density supports this habitat quality in southwestern Utah but not, for the most part, in the eastern portion of the state. This early GAP Model also underestimated the value of habitat in west central Utah. This model's lack of habitat analysis in the northern 1/3 of the state failed to detect the high value habitat in north central Utah.

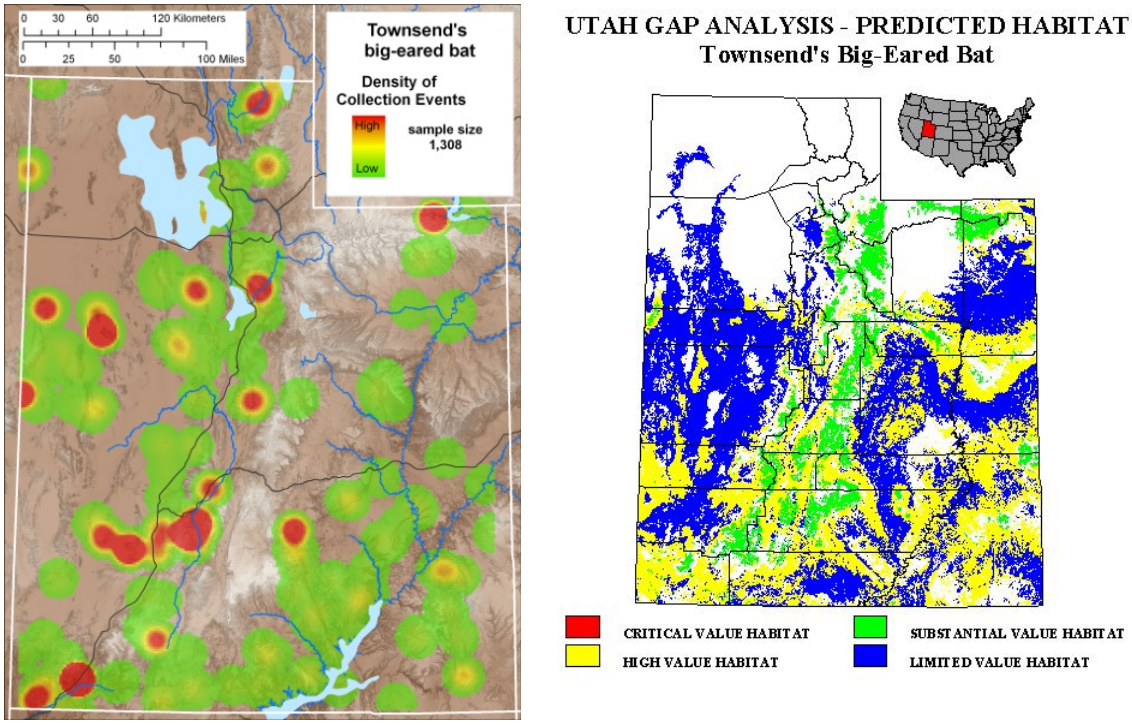

Figure 8. Bat record density produced by the BATBASE data set (left) compared to the GAP Model analysis (right).

Spotted bat density differed from that estimated by the habitat suitability index created by the GAP. The model estimated high and substantial habitats in east central Utah (Fig. 9). The actual density of bat activity supported these findings. However, the BATBASE data also predicts high quality habitat in the southwest and substantial value habitat in central and northwestern Utah.

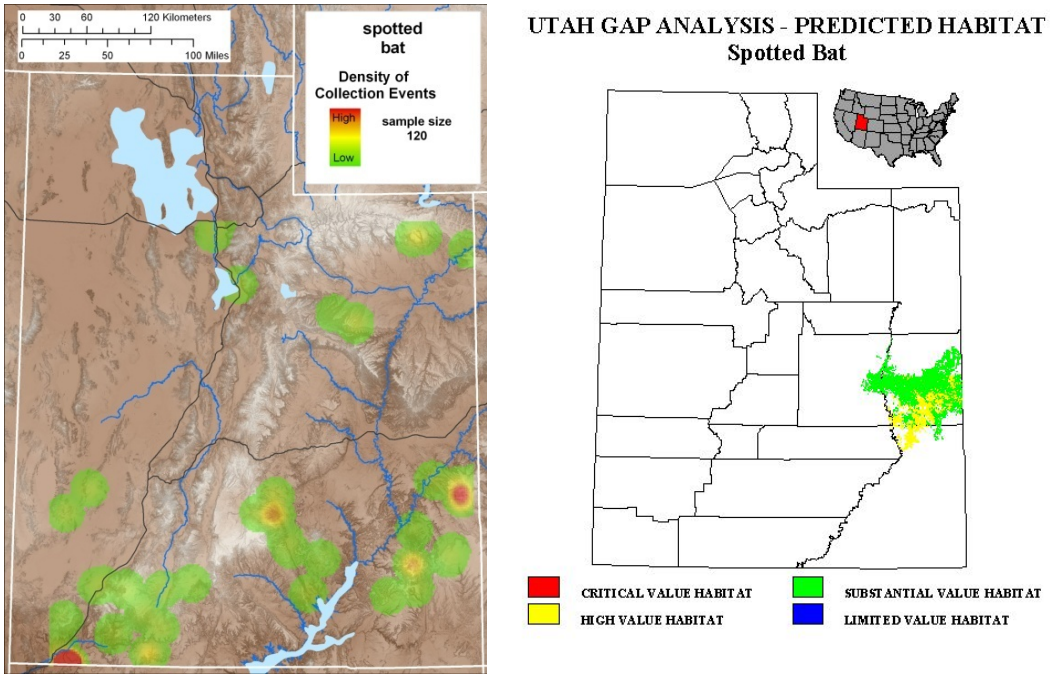

Figure 9. Bat record density produced by the BATBASE data set (left) compared to the GAP Model analysis (right).

Allen's big-eared bat event density varied from that predicted by the GAP (Fig. 10). The GAP model predicted substantial value habitat in extreme southern Utah. The density of Allen's big-eared bat events supported this estimate. However, the highest density of events occurred in southeastern Utah further northern than habitat predicted.

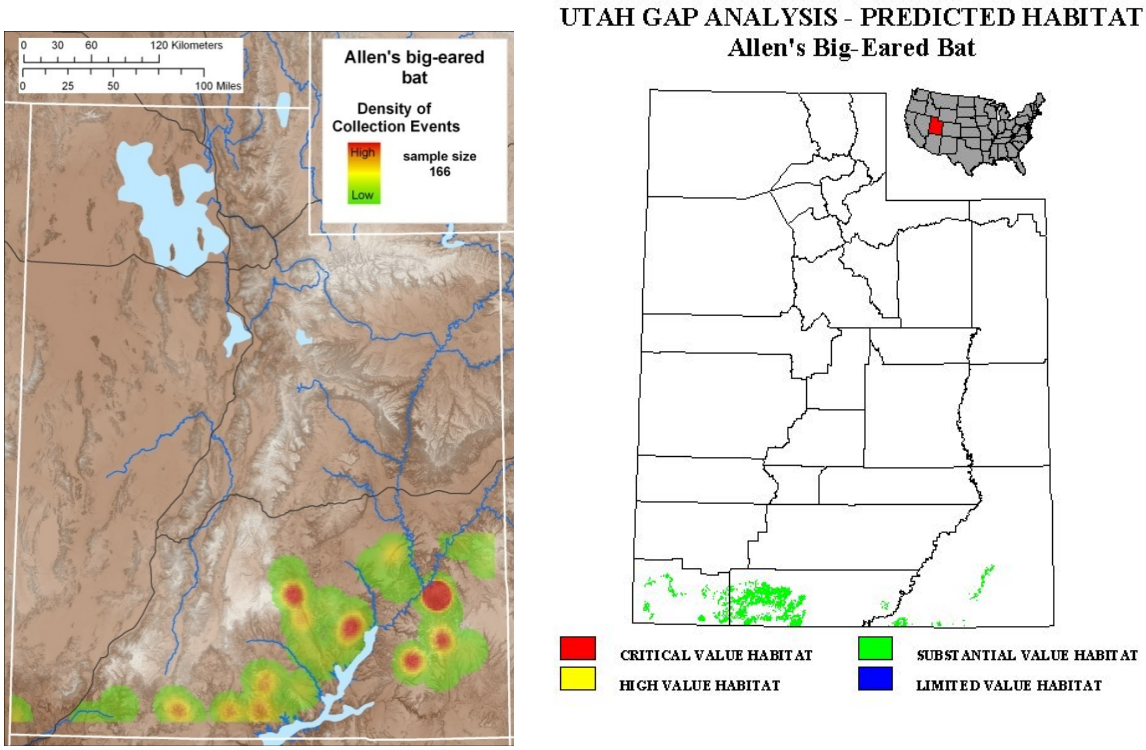

Figure 10. Bat record density produced by the BATBASE data set (left) compared to the GAP Model analysis (right).

Western red bat event density did not substantiate the predicted high value habitat in south and southeastern Utah. Western red bat events were diffuse in Utah. The model failed to predict the suitable habitat in central and northern Utah (Fig. 11).

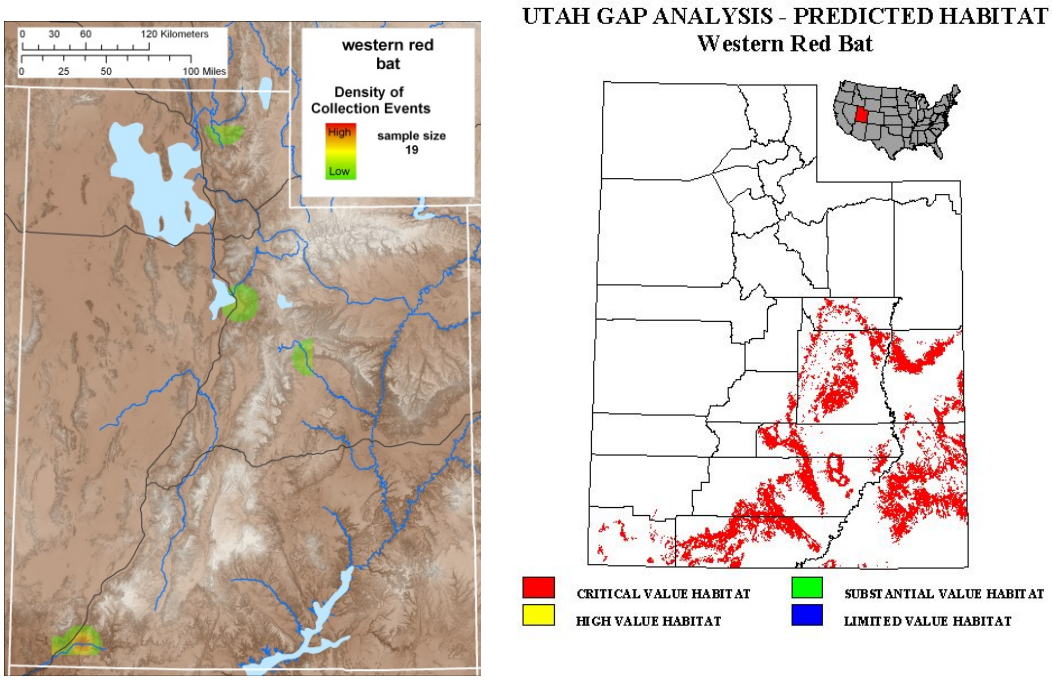

Figure 11. Bat record density produced by the BATBASE data set (left) compared to the GAP Model analysis (right).

Fringed Myotis event density varied from that predicted by the Utah GAP model (Fig. 12). The GAP model predicted substantial value habitat in southern Utah. The BATBASE data set support the location of the habitat but not the value. The high density of fringed myotis activity indicates that this habitat is of a high value. The GAP model did not predict the scattered suitable habitat throughout the rest of Utah.

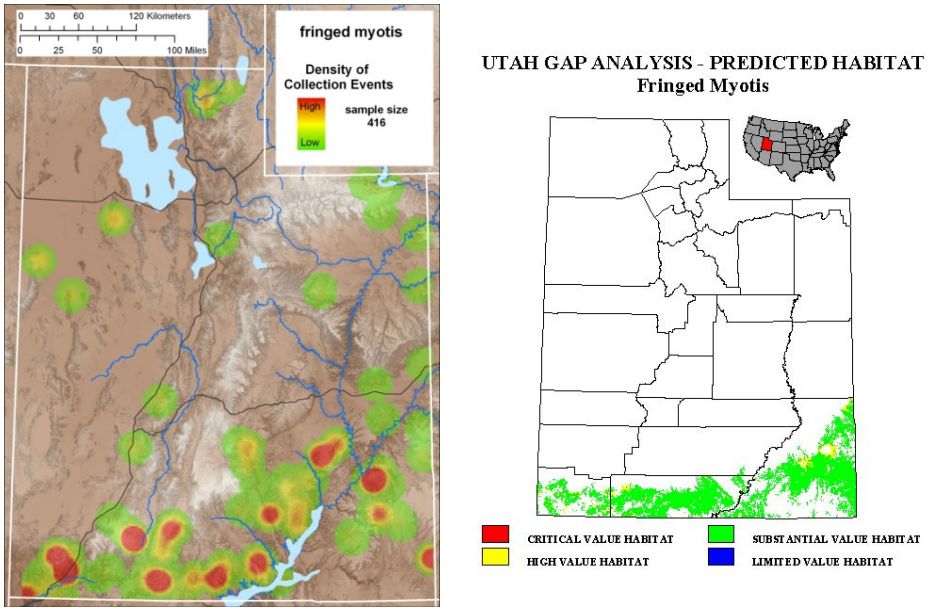

Figure 12. Bat record density produced by the BATBASE data set (left) compared to the GAP Model analysis (right).

The Big free-tailed bat event data and the GAP analysis did not differ substantially (Fig. 13). The GAP model predicted diffuse substantial value habitat throughout Utah. The BATBASE event data supported the model, except where undervaluing montane habitats.

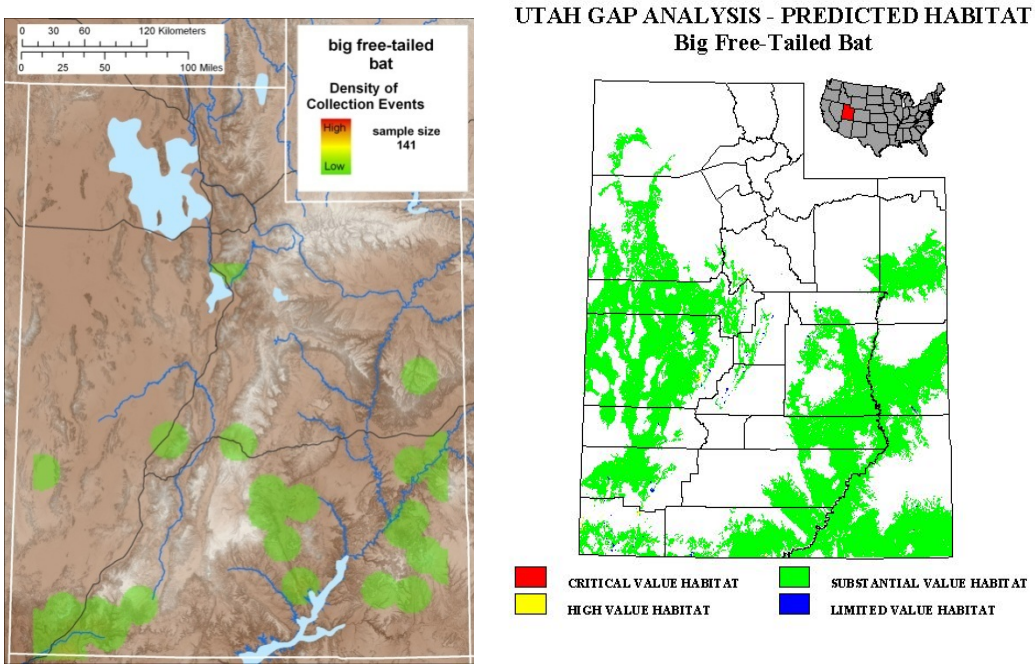

Figure 13. Bat record density produced by the BATBASE data set (left) compared to the GAP Model analysis (right).

DISCUSSION

The BHM provided a vital base layer against which to analyze past and future inventory and monitoring surveys, quantify the effects of current land management practices and disturbances on bats, and provide Utah and all of its cooperators with a data model upon which to set priorities, collaborate on objectives, and emphasize system health. Additionally, the model and its process is portable and scalable, facilitating the expansion of the modeling effort into neighboring states, forests, or districts. The review and refinement of this model with the use of the BATBASE data set and the existing GAP analysis provided a measure of model accuracy and comparison to previous and ongoing research.

The BHM was evaluated with the use of the BATBASE data set. The habitat model and the data set agreed on the value of many habitats and differed across several others. The model predicted high habitat value for montane, woodland and riparian habitats. The BATBASE data observed the highest diversity and density of data in the same habitat types as well as shrublands, grasslands and tundra habitat. These differences are likely the result of synergistic interactions between adjacent habitats. It also illustrates that often habitats are not recognized as suitable until bat occupation has been observed indicating the importance of active management and baseline data collection.

The addition of high value habitat types such as shrublands and grasslands to the BHM leads to some additional patterns observed across landowner types. The initial model predicted low value habitat as the dominant land cover on DoD lands. The addition of the shrubland and invasive perennial grassland categories to the high value habitat category alter our assessment of DoD lands. The high density and diversity of bat activity observed on DoD lands is due to this suitability of habitats before categorized as low value. The DoD landcover not only represents

some current high value habitat but also areas of low value habitat that if restored to full ecological potential would greatly increase the bat habitat value of DoD installations. The recovery of annual forblands to shrublands shows the highest potential for habitat value increase.

Our BHM model failed to detect several high quality habitat types although it predicted habitat value more effectively than the previous models (GAP). The GAP Model analysis predicted some high value habitat for Utah's 6 species of concern while failing to predict many landscape scale patterns. Townsend's big-eared bat habitat was not detected across much of northern Utah and overestimated in southeastern Utah. This failure of detection is likely the result of underestimating the value of woodland and shrublands foraging habitats. The spotted bat habitat model also failed to detect large areas of suitable habitat for this species outside of east central Utah. The Allen's big-eared bat predictive model detected the general habitat trends of this species but not the value of the habitat. The western red bat predictive model noted high value habitat in portions of the state that had no records for this species. The fringed myotis predictive model also detected major trends in habitat suitability but failed to detect suitable habitats in northern and central Utah. The diffuse density of the big free-tailed bat was detected by the model. This failure of this model to detect many suitable habitats is likely the result of underestimating the value of woodland and shrublands foraging habitats.

It is important to note that the model was built using expert opinion- therefore the perceived notion of "good" bat habitat likely drove both the creation of the model and also the survey efforts of the participants. Bat research in the state has already primarily focused on "hotspots" where the probability of capture is high. So using the distribution to confirm the model would be extremely biased towards confirming the utility of the model. For example, the importance of water sources was highly weighted in the model and research supports the

importance of free water for bats- especially in arid environments. However, water sources are also one of the few places where bats can be successfully captured in mist-nets.

The BHM created for the Legacy I project reflects many of the habitat values observed in the BATBASE data set. This model did not align directly with the data set although the two shared many attributes. Our model however did fit the actual data output more completely than the species specific Utah GAP Model. The GAP Model relied on a single landscape characteristic, land cover. In contrast, the BHM was based on the interaction of land cover along with wetland distribution, bedrock geology, elevation, and topographic relief. The edition of these variables and the interaction increased model and accuracy and applicability to land management. By evaluating each of these models with the BATBASE data set we observed the need to expand habitat prediction to multiple variables as occurred with the initial model and the need to evaluate within variable class interactions. The next step in the development of this model is the evaluation of nearest neighbor landscape level habitat interactions.

By evaluating the relationship between bat diversity, density and habitat associations, we have begun a new stage in bat habitat evaluation. This analysis provides a base for future bat habitat modeling and sensitive species monitoring. The patterns observed in this model indicate that a protocol for monitoring bat populations should be fitted to the distribution and habitat associations of the bat species of interest. In addition, the BHM shows that an effective habitat model must take into account the interaction of habitat types. The data set provides the basis of understanding occupancy-based monitoring model. These findings also indicate that there is a need to manage risks and identify threats to bat species as detailed in the Legacy III project proposal.

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