A spatial decision support system to identify species-specific critical habitats based on size and accessibility using US GAP data

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Abstract

The Gap Analysis Program (GAP) is a nationwide effort to find areas of suitable habitat in the US, which if protected from habitat degradation, may help to preserve the native animal and plant biodiversity. In recent years, the GAP protocols used to analyze habitat data have become more scale and species dependent. This research describes the creation of a Spatial Decision Support System (SDSS) that applies species-specific parameters of Individual Area Requirement (IAR) (Vos et al., 2001), Minimum viable population (MVP), and Reach (Allen et al., 2001) to determine critical habitats for animal species, thereby eliminating those areas that are effectively unusable because of size or inaccessibility. The utility of the SDSS, and the three algorithms contained within it (i.e., core area, core area growth and aggregate), is demonstrated by creating distribution maps of usable habitat for five species (i.e., alligator, black bear, bobcat, gray fox and wild turkey) commonly found in the state of Arkansas. This knowledge can then be used to guide and prioritize conservation efforts towards protecting usable, and often critical, habitats.

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Keywords: GAP; Spatial decision support systems; Individual area requirement (IAR); Minimum viable population (MVP); Reach

Software availability

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First available 2002.
Software required Arcview® 3.2 (with Spatial Analyst and Dialog Designer extensions)
Program language Avenue
Program size 281 kb (3.4 MB with sample dataset)
Cost and distribution Available free via email from B. Larson (larson505@netzero.com)

1. Introduction

While extinction is a natural process, many scientists believe that we are in the midst of the sixth great extinction in geologic history (May et al., 1995). And unlike previous extinction events, the current decline in biological diversity is being driven by anthropogenic activities (Chapin et al., 2000). The extinction rates among a wide variety of organisms are currently 100–1000 times their pre-human rates (Pimm et al., 1995). Most certainly, the primary cause of this decline has been and will continue to be the loss of habitat due to human expansion and development (Sala et al., 2000). Given the current crises involving the loss of biological diversity on the planet, extensive efforts are underway to study and quantify existing habitat, with the overall goal of protecting and preserving critical areas.

In its most basic form, ‘gap analysis’ is the term applied to the process of overlaying species distribution maps with land management data in an effort to identify gaps (i.e., unprotected habitat areas) in the current conservation system (Scott et al., 1993) (Fig. 1). The analysis is done in three steps. First, suitable habitat areas are identified using remotely sensed data. Second, those areas where the species in question has not been observed are excluded from further consideration.
Finally, the remaining areas are overlaid on a map of conservation areas to find unprotected habitat with the intention of preserving them. A concerted nationwide effort of this type has been in progress in the United States for some years now in the form of the National Gap Analysis Program (GAP) (US Geological Survey, 2002). It is being conducted at the state level, and is coordinated by the US Geological Survey Biological Resources Division. Other countries, such as Canada and Australia, have also expressed interest in this program.

Despite its obvious need, there has been some criticism directed at the original methodology used by the GAP program to generate habitat information. Primary among them is that important information about scale of analysis and requirements of specific species are ignored by the analysis techniques used. To overcome these limitations, current methodologies are beginning to incorporate species-specific information into consideration while evaluating and prioritizing habitats for protection, such as the minimum area required to support a viable population and accessibility (Allen et al., 2001).

This paper details the development of a Spatial Decision Support System (SDSS) that applies a set of species-specific parameters to the landcover dataset to identify usable, and often critical habitats as a function of their size and accessibility. In the past, analytical capabilities of GIS have been used along with remotely-sensed data to support the process of identifying suitable habitats for specific species (Agee et al., 1989; Aspinall and Veitch, 1993; Rosenberry et al., 1994). Recently, Ranci Ortigosa et al. (2000) used a GIS-based decision support system in order to assess the suitability of a habitat to support a specific species based on factors such as topography, vegetation, and size. However, none of the studies listed above considered accessibility of the habitats as one of the factors controlling its usability by a specific species.

The utility of the proposed SDSS in determining suitable habitats based on size and accessibility, using the US National Gap Analysis Program (GAP) datasets for the state of Arkansas, for five different species (i.e., alligator, black bear, bobcat, gray fox and wild turkey) is explored.

2. Background information

2.1. The National Gap Analysis Program (GAP)

The GAP Analysis Program is administered by the National Biological Service of United States Geologic Survey. However, the bulk of the work is being undertaken at the state level by a multitude of collaborating federal, state, and local organizations. Each state is charged with individually organizing, compiling, and formatting all of the data layers required, based on national guidelines. Geographical Information Systems (GIS) technology is used to compose and analyze the layers of spatial data (Scott, 2000).

The gap analysis process begins with an assessment of the vegetative cover of an entire state. Vegetation is generally identified to the alliance level (groups of plant associations sharing one or more dominant species) based on the National Vegetation Classification System. Remotely sensed Landsat TM satellite data is used as the basis for determining vegetative alliance distributions at a resolution of 30 m. Various techniques are used to evaluate the accuracy of such maps with the goal of achieving a minimum of 80% accuracy. Ground-truthing efforts take the form of a combination of aerial photo-
graphs, other accuracy assessed vegetation maps, and field-gathered data (Stoms, 2000).

The next stage in gap analysis involves mapping the predicted distributions for all terrestrial vertebrate species found within a given state. In order to map predicted distributions, habitat associations (as derived from the scientific literature and expert opinion) and known occurrences of species (as derived from state biological survey and natural heritage programs) are combined. To evaluate known occurrences or basic range of a species, the area to be studied is divided up into EPA Ecological Mapping and Assessment Program (EMAP) hexagon grids (~635 km²) (Fig. 2). Each hexagon within a state is identified as either constituting an element of the known range for a species or as being an area outside of the known range. If a species is known to occur in a given area, as signified by a recorded occurrence within a hexagon, then the species is predicted to inhabit all of its associated habitat type in that area. If the species has no record of occurrence in a given area, then even if there is associated habitat in that area, it is not included in the predicted distribution. Through this process, detailed layers of spatial distributions can be produced for all of the terrestrial vertebrate species found within a state. Distribution layers are specified to be produced at a resolution of at least 1:100,000 (Stoms, 2000).

The final data layer that is needed to complete the gap analysis process is that of land stewardship. In this layer, land parcels with a minimum resolution of 16 ha are categorized into four classes of land stewardship according to their ownership and management status, with the classes 1 and 2 used to identify lands dedicated specifically for the purposes of conservation (Crist, 2000a). For public lands, the agency responsible for management of the land is also identified. The primary objective of the final GAP layer is to quantify the presence of protected and unprotected habitat, under both private and public ownership, within a state.

Central to the purpose of creating GAP datasets is to use it to identify areas that, if protected over sufficient time, may yield long-term benefits in maintaining critical levels of biodiversity. As it is explicitly stated in the GAP Handbook, GAP is meant to compliment species-specific conservation efforts (i.e. the Endangered Species Act) by preventing the creation of more endangered and threatened species (Scott, 2000).

However, critics of the original program have argued that there exist fundamental methodological shortcomings within the GAP program. Among these criticisms, Williams (1996) argued that the sharp distinctions made between vegetative communities cannot accurately represent the subtle changes that exist in many ecosystems. Equally, Conroy and Noon (1996) pointed out that the predicted species distributions contain unknown amounts of error that may lead to erroneous decision-making. Both of these sources cited the fact that much of the content of GAP is scale and species dependent. Treating widely varying species the same in terms of predicting distributions is certainly going to introduce error into the process. An isolated hectare of forest might provide usable habitat for a population of squirrels, but would be essentially useless to even a single black bear. Indeed Allen et al. (2001) point out that the fragmented condition of many landscapes result in patches that are too small to support viable populations of larger species. Under original GAP methodology, a hectare of forested land could potentially be categorized as potential habitat for any number of species (if individuals of each species were known to exist in that area as depicted by the EMAP hexagons noted earlier). Further, distance between the patches might be crucial in determining if these patches are too isolated to be of value to a species of interest. These concerns are even conceded to in the GAP handbook (Crist, 2000b), and are being currently addressed by GAP researchers.

In response to these criticism, researchers have focused on the applicability of species-specific landscape ecology parameters (such as the minimum area required to support a viable population) to identify the consequences of fragmentation and the creation of a large number of small and spatially isolated patches of habitat (Allen et al., 2001). Further, as part of the North Dakota GAP Analysis Program, species-specific habitat suitability mapping is being carried out by the Northern Prairie Wildlife Research Center (NPWRC) that includes a wildlife habitat relationship (WHR) model for 289 breeding terrestrial vertebrate species (NPWRC, 2001). These factors were taken into consideration in the creation the SDSS described here, where the suitability of habitat areas identified by original GAP procedures are evaluated using a landscape ecology approach.
2.2. A landscape ecology approach to enhancing the value of the GAP dataset

While traditional ecology has focused on the processes and interactions of natural systems, landscape ecology has added a spatial component that was previously not fully addressed (Pickett and Cadenasso, 1995). In landscape ecology, spatial factors are considered influential elements of ecosystem interactions.

According to the principles of landscape ecology, species survival is most impacted when anthropogenic development causes large-scale fragmentation of the landscape. As habitat is destroyed, the remaining natural ecosystems are continually encroached upon and subdivided. As posited by Island Biogeography Theory (MacArthur and Wilson, 2001), the relative size of habitat fragments (or patches) and their relative isolation then play a key role in determining how many species can be supported. The general trend is that as the size of a patch decreases, the number of species declines (Foreman, 1995). This is compounded by increasing spatial isolation of highly fragmented patches from one another. As habitats are divided and the distances between fragments increase, remaining populations become isolated (Opdam et al., 1993; Noon et al., 1997). Subsequently, isolated populations become vulnerable to extinction due to a number of factors: genetic degradation (from genetic drift and inbreeding), demographic stochasticity (random changes in birth and death rates due to variations in age and sex ratios), and environmental fluctuations (fire, flood, food supply, etc) (Foreman, 1995; Noss and Cooperrider, 1994). The degree of isolation of a population depends on a number of factors. The distance between any remaining patches will certainly influence the ability of a metapopulation of a given species to interact and interbreed. The scale-dependant factors of species size and dispersal ability come into effect. Obviously, birds have an easier time traversing openings in habitats than do most other types of animals. But, such considerations apply to all species. While most animals’ ranges tend to be limited by human development, others, such as the white tailed deer, are quite adaptable. As such, dispersal capabilities are going to play an important role in the amount of habitat a given population is able to access.

2.3. Species-specific parameters: individual area requirement, minimum viable population and Reach

Three species-specific landscape ecology parameters deemed necessary in maintaining a viable metapopulation of a given species in an area (Vos et al., 2001; Allen et al., 2001), were utilized in the creation of the proposed SDSS. These are: individual area requirement (IAR), minimum viable population (MVP), and Reach. These three parameters serve to identify the habitat size and accessibility requirements for a given species. IAR refers to the minimum area of habitat needed to support a reproductive pair of individuals of a species (Vos et al., 2001). MVP refers to the number of individuals necessary to sustain a population (Allen et al., 2001). Reach is a general assessment of the distance a given species might conceivably be able to travel outside of its habitat during its normal food and water gathering routine (Allen et al., 2001). In Euclidian space, it can be defined as a zone of a specified distance around a fragment of habitat. It is presumed that if a fragment of habitat lies within ‘Reach’ of another fragment, defined according to the mobility of a species, then the two fragments can be considered to be contiguous for the purposes of defining a habitat area. Therefore, Reach is a measure of the accessibility of a fragment from other adjacent fragments. The use of these three parameters (i.e., IAR, MVP and Reach), therefore, produce maps of potential species richness that are more conservative and defensible than habitat maps devised using original GAP methodology.

3. Architecture of the spatial decision support system

3.1. Algorithms utilized within the SDSS

A spatial decision support system (SDSS) constitutes an effective means to examine the influence of species-specific parameters (i.e., IAR, MVP and Reach) on suitability of habitat patches on a larger, state-wide scale. Further, suitability of habitats based on accessibility (measured as the outward diffusion of species from a ‘core area’) can also be evaluated within the SDSS.

Densham (1991) defined SDSSs as systems that provide flexible problem-solving environments for decision-makers to research complex spatial problems. An SDSS allows for iterative problem solving by allowing the generation of multiple solution-scenarios to answer what-if? types of queries. Densham cites two distinct benefits of using an SDSS: (i) increasing the level of understanding of a problem and (ii) evaluating the trade-offs between the various solution scenarios.

For the SDSS, three separate algorithms were developed that utilized the parameters of IAR, MVP and Reach to identify habitats usable by a specific species. The first algorithm, simply referred to as the ‘core area’ (CA) algorithm (after Allen et al., 2001), follows a simple methodology whereby the largest fragments are identified, and all additional habitat patches within a certain distance of the core areas (i.e., Reach) are included in the final estimate of available habitat (Fig. 3). The ‘core area’ reflects the total amount of habitat required to maintain a viable population (identified in this study as being at least equal to or greater than IAR * MVP). Note that there is another parameter discussed by Allen
et al. (2001) called Minimum Critical Area (MCA) that reflects the core area requirement of a viable metapopulation, and can substitute for the IAR * MVP formula in the SDSS. Further, because MCA takes into account overlap between area requirements of individuals, it is perhaps a more accurate measure of the core area requirement. However, region-specific MCA values for species of interest can be difficult to find in scientific literature.

The other two algorithms, ‘core area growth’ (CAG) and ‘aggregate’ (AG), devised as part of the SDSS, employ GIS functionality (i.e., buffering) and a diffusion approach to incorporate additional patches within the maximum distance specified by Reach. Reach, therefore, provides the maximum distance used by these algorithms for the inclusion of outlying patches.

In the CAG algorithm, each patch of usable habitat is repeatedly evaluated in a radial fashion outwards from the core areas (Fig. 4). The rationale for utilizing this approach is the fact that once species colonize the patches adjoining core areas, they could use them as a base for populating other outlying fragments. With each iteration of this algorithm, additional, reachable habitat patches become part of the core area. The new core area then forms the launching point for the next extension. This process is continued till no further habitat areas can be added to create new core areas.

The AG algorithm somewhat modifies the concept of a core area (Fig. 5). It is based on the hypothesis that a highly fragmented landscape may still contain a large number of small patches, which when taken together are adequate to support a viable population of a given species without the need for a wholly cohesive core unit. This algorithm first groups patches by utilizing ‘Reach’ as the maximum distance within which isolated fragments will be aggregated. The core area requirement is then estimated on the total area of the grouped patches.

3.2. Working with the SDSS

A GIS software, Arcview 3.2 (with Spatial Analyst and Dialog Designer extensions), was used as the basis upon which to build the SDSS. Avenue, the scripting language available within Arcview, was used to customize the Arcview interface and to implement the algorithms. Most of the analysis was performed in raster mode, which is the native format of the GAP datasets released by the state agencies. The customized toolbar of the SDSS is shown in Fig. 6, while Fig. 7 depicts the flowchart of the program logic.

A database file (in ‘Dbase’ file format), containing information about all the species found within a geographic region, is utilized to store species-specific ecological information within the SDSS (Fig. 8). While this file only contains animal species specific to the state of Arkansas at present, information about species in other states and countries can be added easily. The columns specified within the file are as follows: Sp—code (Nature Conservancy Species Code; where the first three alphabets help distinguish between amphibian, avian, mammalian and reptilian species), Sp—name (common name), Sci—name (scientific name), IAR (individual area requirement), MVP (minimum viable population), and Reach (home range-based reach distance). Addition-

Fig. 3. A synopsis of the ‘core-area’ algorithm.
ally, the SDSS requires the following two spatial datasets for the area of interest from the US Geological Survey (2002) National GAP program website:

1. Landcover data indicating areas of usable habitat (usually generated by reclassifying Landsat TM satellite imagery to identify forested landscapes). This file is available in ESRI ARC/INFO® raster data format.
2. Land-management data layer consisting of polygons delineating location of all conservation land and their classes. This file is available in ESRI shapefile format.

Actual operation of the SDSS follows a very simple progression. To initiate the program and begin the analysis process, the user can click on the ‘GAP’ button located in the toolbar (see Fig. 6). Upon pressing this button, a dialog box appears which allows the user to select the species of interest (Fig. 9). The ‘Continue’ button located in the upper right-hand portion of this dialog box brings up a second dialog box which can be used to enter or update all of the species-specific parameters (i.e., IAR, MVP and Reach) for the selected species (Fig. 10). The second dialog box also has three buttons that allows the user to execute one of the three algorithms described earlier (i.e., CA, CAG, and AG).

The results are presented to the user in the form of recalculated raster distributions and accompanying attribute tables. Fig. 11 shows the results of applying the CA algorithm on landcover data for Arkansas using species-specific information for Wild Turkey. As indicated in the graphic and the accompanying table, given a set of IAR, MVP and Reach parameters, 106, 108.7 ha of potential habitat was considered unusable from a conservation standpoint by the CA algorithm.

The next section discusses the management implications of using this SDSS for prioritizing protection of habitat areas for five species (i.e., alligator, black bear, bobcat, gray fox and wild turkey) based on accessibility and size.

4. Applying the spatial decision support system to Arkansas

To provide an example of the use of the SDSS (and the three algorithms contained therein) in supporting
decision-making, landcover and land stewardship datasets for Arkansas were acquired from the US Geological Survey GAP Analysis Program data download web site (US Geological Survey, 2002). Data representing IAR, MVP and Reach for five species commonly found in the region (i.e., alligator, black bear, bobcat, gray fox and wild turkey) were obtained from a review of pertinent literature. While the use of Minimum Critical Values (MCA) values is ideal for evaluating habitat suitability, and is becoming more readily available (Landry et al., 2001), it can be difficult to find region and species specific MCA data in current scientific literature. However, the SDSS is designed to accept MCA values as and when they become available.

The IAR of a specific species is defined as ‘the area required for a reproductive unit, e.g., the territory of a pair of birds’ (Vos et al., 2001, p. 25). Therefore, density values (i.e., the number of individuals per unit area) obtained from the literature were used to determine the IAR value for a species [Table 1(a)]. IAR values were assumed to be twice the density estimates shown in Table 1(a), and converted to consistent ‘hectares per reproductive pair’ for use in the SDSS (Table 2). If a range of values was presented in the literature, the aver-
Fig. 8. The database table containing species-specific information needed to operate the SDSS.

Fig. 9. Dialog box that allows users to select a specific species.

Fig. 10. Dialog box that allows users to edit species-specific parameters.

The number of 50 was chosen as the standard value of MVP for all species (after Allen et al., 2001). This number was based on some minimal estimations of general population viability. While the use of a single value for all species was somewhat contrary to the goal of the study (i.e., to differentiate species habitat based on IAR, MVP and Reach), it is relatively easy to change these values within the SDSS when necessary.

The calculation of Reach values represent a slight deviation from the methodology employed by Allen et al. (2001). While Allen et al. (2001) utilized dispersal (e.g., the distances traveled to establish a new territory) as being equivalent to Reach, this often represents the maximum distance journeyed by individuals. Longer distances mean that the individual must expend more energy in routine activities such as foraging. However, distances between patches of exploitable habitat must allow for a net gain in terms of energy. For this reason, it was assumed that any realistic Reach distance would lie somewhere within the average-sized home range for a species. The home range is simply the geographic extent covered by a single animal for routine activities. Average home range values for a species were obtained from literature review of studies near Arkansas [Table 1(b)], and area-equivalent circles having the same area as the home ranges were calculated. The diameters of these circles were then used as estimates of Reach values.

Spatial accessibility and viability of potential habitat areas for each of the five species was analyzed by utilizing the three algorithms encoded into the SDSS (i.e., CA, CAG, and AG). The primary concern was the amount and percentage of habitat rendered unusable as a result of implementing size and accessibility restrictions. As an example, the spatial distributions of usable and unusable habitats for bobcat generated by using the CA, CAG and AG algorithms are shown in Fig. 12. The SDSS can also determine the percentage of habitat specifically managed for conservation purposes that would be considered unusable on the basis of the size and accessibility. The percentage reduction of overall habitat, as well as conservation-managed habitat, for the five species (i.e., alligator, black bear, bobcat, gray fox and wild turkey), is compared to total habitat areas identified by the original Arkansas GAP data, and the results are listed in Table 2.

5. Management implications and the black bears in Arkansas

In the case of the SDSS presented here, land managers charged with preventing habitat loss could use the SDSS to identify critical areas for protection based on size and accessibility. Further, the SDSS can also be used to determine the effects of applying different values of the species-specific parameters IAR, MVP (or MCA, if available) and Reach on various habitat patches. This ability to quickly and easily determine the effects of varying values of the parameters will undoubtedly
increase the understanding of how important those parameters are to predicting species distributions and to the cumulative effect on species richness values.

One utility of this SDSS is its ability to raise important questions about the long-term viability of a species in relation to the location of conservation-managed lands. Consider the case of black bear habitat in Arkansas. The black bears’ primary habitat is in the mountainous northwestern part of the state. But a significant tract of habitat extends down into the Mississippi delta region of the state, and a large tract of land (64,750 ha) is protected there by the White River National Wildlife Refuge (Fig. 13). Given the area and accessibility requirements of the black bear (as determined by the use of the CA...
Table 2
Reduction in usable habitat observed by applying the core-area algorithm

<table>
<thead>
<tr>
<th>Parameters</th>
<th>MVP</th>
<th>IAR (ha)</th>
<th>Reach (km)</th>
<th>Loss (ha)</th>
<th>% Loss</th>
<th>% Cons loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>American alligator</td>
<td>50</td>
<td>3.22</td>
<td>1.09</td>
<td>61,543.8</td>
<td>3.999</td>
<td>0.007</td>
</tr>
<tr>
<td>Black bear</td>
<td>50</td>
<td>2424.24</td>
<td>10.16</td>
<td>348,262.8</td>
<td>7.915</td>
<td>35.018</td>
</tr>
<tr>
<td>Bobcat</td>
<td>50</td>
<td>80</td>
<td>1.91</td>
<td>279,524.5</td>
<td>3.841</td>
<td>2.003</td>
</tr>
<tr>
<td>Gray fox</td>
<td>50</td>
<td>133.34</td>
<td>2.12</td>
<td>245,507.0</td>
<td>2.99</td>
<td>1.336</td>
</tr>
<tr>
<td>Wild turkey</td>
<td>50</td>
<td>33.62</td>
<td>1.29</td>
<td>217,591.1</td>
<td>2.992</td>
<td>0.9</td>
</tr>
</tbody>
</table>

This example illustrates the critical role the GIS-based SDSS described here may play in future conservation-planning efforts.

6. Conclusions

The Gap Analysis Program (GAP) is an ongoing effort in the United States to identify gaps (i.e., unprotected habitat areas) in the current conservation system, and find areas which, if protected over a sufficient period of time, may yield long-term benefits in terms of maintaining critical levels of biodiversity. However, researchers have argued that much of the content of the
original GAP program is scale and species dependent, a fact that is largely ignored by current protocols used to analyze habitat data. Further, factors of patch size and distance in fragmented landscapes were also not considered by GAP. In a study conducted in Florida, Allen et al. (2001) utilized the species-specific parameters MCA, MVP, and Reach to restrict the total amount of usable habitats by specific species. This analysis produced species richness maps that were more conservative and defensible. Similar wildlife habitat suitability measures, including MCA, are now being incorporated by several states in their GAP programs.

In this paper, we utilized the parameters proposed by Vos et al. (2001) and Allen et al. (2001) within a SDSS consisting of three algorithms (i.e., CA, CAG, and AG), a database of animal species, and two spatial datasets (i.e., GAP and data stewardship data) to identify usable habitats based on size and accessibility. The utility of the SDSS is demonstrated by identifying usable and unusable habitat areas from the GAP dataset for five species (i.e., alligator, black bear, bobcat, gray fox and wild turkey) commonly found in the state of Arkansas.

The examples presented in this paper indicate that the SDSS is a powerful tool that can be used by land managers to estimate critical habitat areas for preservation by employing different species-specific parameters. However, the effectiveness of the results generated by the SDSS is currently limited by the quality of the GAP data available to perform such analyses. The resolution and accuracy of remotely-sensed vegetation classification and habitat identification needs improvement. Equally, an enhanced understanding of the ecological principles involved in determining species distributions and the corresponding parameters (i.e., IAR, MVP, and Reach) is required in order to establish the validity of results generated by the SDSS. Further, Reach, as defined here, is simply the Euclidian distance from one fragment to another that determines its accessibility by a species. However, direction may be as important as distance in determining accessibility. Indeed, more sophisticated methods of measuring accessibility between habitat patches using graph-theoretic approaches have been discussed in the literature (Urban and Keitt, 2001), and will be incorporated into future versions of the SDSS.

Even with these limitations in existence, the current SDSS provides an increased level of understanding of how a species interacts with a specific habitat distribution. Knowing what geographic areas are critical for a given species allows for preemptive actions to be taken to protect these areas, as is the case with the black bears in Arkansas. Ultimately, it is this type of understanding that can be used to guide and prioritize conservation efforts.

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