

Developing the Adaptive Components of the Suitable Pronghorn Environment Envelope, Determined by GIS Outputs, Arrays, and Transformations (SPEEDGOAT) Model.

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Abstract

Although major migration routes and corridors for Pronghorn (*Antilocapra Americana*) are well known, current and future land use and management decisions may block, fracture, or otherwise disrupt these routes. The development of a management tool that can assist in determining where conditions are suitable for Pronghorn migration, based on a set of species specific criteria, becomes a valuable asset in managing the pronghorn population. This paper discusses a GIS based model, the Suitable Pronghorn Environment Envelope, Determined by GIS Outputs, Arrays, and Transformations (SPEEDGOAT), that can forecast suitable species habitat and can assist with Pronghorn management goals within the state of Wyoming. This paper outlines the steps in building and refining the model, validates its accuracy, and summarizes how the model can be utilized in a decision support capacity. Given that there are certain limitations to predictive models, the role and application of an adaptive approach to data integration and model execution is evaluated; furthermore, the caveats and opportunities of the adaptive application are illustrated.

Background and Rationale

Wyoming's economy depends heavily upon the utilization of natural resources (Wyoming Department of Administration and Information, 2003). Thus pronghorn and other big game species must be managed in a way to protect and preserve the wellbeing of the species as a whole. To this end the Wyoming Game and Fish Department (WGFD) routinely documents the locations, migration routes, and ranges of pronghorn within the state (Wyoming Game & Fish, 2005). However, this documentation is based upon generalized trends and observations from wildlife biologists throughout the state. Consequently, there is a lack of consistency and accuracy in the current documentation. As the population of the state grows, new urban development, expansion of existing gas and oil fields, new road creation, and other factors commonly correlated with population increase have the potential to negatively affect the status of pronghorn if proper management techniques are not implemented. Furthermore, current and future land use and management decisions may block, fracture, or otherwise disrupt pronghorn routes and ranges.

The development of a management tool that can assist in determining where conditions are suitable for pronghorn migration, based on a set of species specific criteria, thus becomes a valuable asset in the management of said species. A GIS based model that forecasts pronghorn habitat can assist in meeting species management goals within the state of Wyoming. The basic principles behind such a GIS model are not new, however when the functionality of GIS software tools is combined to form a model, it becomes a value added product that serves as a powerful tool in the decision support process. The development of SPEEDGOAT gives a user such as wildlife biologists, land management planners, and NGOs the ability to implement a tool that can take advantage of the best practice strategies for aiding in the management of pronghorn.

The results from the SPEEDGOAT model adequately forecast suitable habitat for pronghorn. Thus the tool can effectively be used in the decision support process to help determine how the pronghorn species and its suitable habitat are managed. Additionally, based on the model output, a second tool that establishes the longest potential migration path for any given pronghorn herd within Wyoming, serves to enhance the management capabilities established by this project.

The value of each of these tools to specific users like wildlife biologists, land management planners, and non-government organizations (NGOs) is significant as it offers additional information to the decision making process. Furthermore, the design and implementation of user-interfaces for each tool effectively enhances this value by enabling these users to access the power of the tool without in-depth GIS training. Hence, the tool can effectively assist in pronghorn management decisions. Additionally, there are certain limitations to predictive models, thus application of an adaptive approach to data integration converts a static model to one that can adapt to changes in habitat, species knowledge, or management decisions.

Pronghorn Characteristics

A successful model must adequately represent the environment in which it is an abstraction; hence the need to sufficiently research key pronghorn habitat and migration patterns was essential to the development of SPEEDGOAT and the associated tools. This research concentrated on five important factors; terrain, vegetation, water, barriers, and snowpack.

Terrain

Peak concentrations of North American pronghorn herds are located between 1200-1850 meters above sea level, but have been found to exist at elevations outside that range (Yoakum, 1978). Furthermore Yoakum et al. (1996) reported that pronghorn tend to reside in habitat with rolling hills and low lying areas where slopes are less than 30%. These findings were verified by Ockenfels (1994) and Lee et al. (1998), who reported that pronghorn circumvent slopes of 20% or greater, and apparently prefer areas where the slopes are less than 10%. However, pronghorn do seem to prefer variance in their desired habitat. During harsh winters, pronghorn have been found in areas of topographic variance. These areas appear to offer a variety of habitat requirements, including wind blown ridges, and southern facing exposures which provide access to vegetation (Bruns, 1977; Cook, 1984).

Vegetation

Pronghorn tend to move more than other similar ungulates, thus they tend to select the most nutrient rich vegetation available. In all cases, pronghorn will select forbs, shrubs, and then grasses, in said order (Yoakum et al., 1996). However, pronghorn also need a variety in available vegetation. A study by Ellis (1970) tied the availability of a combination of grasses and shrubs to the fawn survival rate. An additional study also concluded that if pronghorn are limited to only one type of vegetation they may starve to death (Martinka, 1967). In fact, between 30 and 50 percent vegetative ground cover consisting of varied vegetation is a staple of pronghorn habitats (Yoakum et al., 1996).

Water

Pronghorn are usually found within 1.5 – 6.5 km of a water source (Yoakum et al., 1996). They require a steady supply of water, which can be obtained from snow, lakes, streams, ponds, natural springs, and livestock water stores (Yoakum, 1978). In the Red Desert, Wyoming; an aerial survey found that nearly 95 percent of all pronghorn were within 4.5 – 6.5 km of a visible water source (Sundstrom, 1968). In fact, their need for water is so great that Pronghorn will kill themselves trying to navigate through barriers to get to a supply of water (Baker et al, 1953).

Barriers

Pronghorn are adverse to jumping fences, and will in most circumstances choose to go under a fence. Thus fences, especially woven wire fences, form barriers that significantly restrict pronghorn movement. Additionally roads and railroads also act as barriers to movement; plus the barrier effect is increased by the use of fences along the road and railroad right-of-way (Jaeger & Fahrig, 2004). Other barriers, such as urban sprawl and gas field development may also influence Pronghorn migration, however such effects are currently unknown (Sawyer & Lindzey, 2000).

Snowpack

Pronghorn movements seem to be triggered by seasonal changes, and the distance traveled seems to be directly correlated to snow depth (Yoakum, 1978). Once snow depth reaches 15 cm, it begins to cover certain vegetation, making it difficult for Pronghorn to acquire preferred food (Rouse, 1959). Furthermore, approximately 30 cm of snow depth seems to trigger a pronghorn's instincts to move to more suitable habitat, because once snow depth levels reach 46 cm movement is significantly and even morbidly restricted (Gunzel, 1982).

Upon final determination of important variables, exploratory data analysis and collection was conducted to find suitable data for use in the model. Table 1 illustrates the source of each dataset used during this project. It is important to note there is no snowpack data listed. Although literature suggests that snow, more specifically snow depth, does affect pronghorn locations, data suitable for this analysis was unavailable.

The definition of pronghorn habitat requires multiple factors of certain input themes. These transformations allow for more complex interactions such as terrain and vegetation variety to be considered in the SPEEDGOAT model. Each transformation was accomplished using GIS software and is documented as follows.

The raster environment allows for transformations of continuous data that the vector environment does not. Two such methods were utilized for SPEEDGOAT sub-models. A focal variety analysis determines the number of unique values surrounding a particular value and

returns it as that locations variety. This type of analysis was used to expose specific variations key to pronghorn habitat. The second method, a slope analysis, identifies the steepest slope for any given location and returns that as the value. These calculations are derived from an elevation model of the user's choice and the results can be reported in either percent or degrees.

Often times datasets are created for a specific purpose, and may have unneeded information, thus the data must be consolidated to meet the projects goals. Two different methods of data consolidation were implemented for the SPEEDGOAT model. The first method was attribute selection which allows the user to select the data of choice based upon the attributes of specific features. The other method of data consolidation is reclassification. Reclassification techniques allow user defined categories of unique data to be consolidated into groups, thus transforming the data to meet the projects requirements.

In contrast, certain datasets don't include enough information, thus several data sources need to be combined to adequately represent the desired theme. This process is known as merging or appending, and effectively combines the features from several different sources into one output layer.

Data	Source	Transformations
<i>Pronghorn Seasonal Ranges</i>	WYGISC	None
<i>Pronghorn Migration Corridors</i>	WYGISC	None
<i>Pronghorn Telemetry Points (1).</i>	Sawyer, H., F. Lindzey, and D. McWhirter. 2005	None
<i>Pronghorn Telemetry Points (2).</i>	Sheldon, Daly. 2005	None
<i>Land Cover (Vegetation Index)</i>	WYGISC	Reclassification; Focal Variety
<i>Water (Water Index)</i>	WYGISC	Selection of Specific Water Sources
<i>Elevation (Terrain Index)</i>	WYGISC	Slope; Focal Variety
<i>Barriers (Barriers Index)</i>	WYGISC & BLM (Pinedale Field Office).	Merging of Roads, Railroads, and Fences

Table 1: SPEEDGOAT Data Sources and Transformations

Methods

“Geographic information systems (GISs) are computer software programs specifically designed to assist in the solution of geographic problems. But they are much more than that. They automate known geographic concepts and ideas; provide tools and justifications for geographic decision making; render explanations of distributional patterns of people, plants, animals, places, and things; and even predict new distributions and spatial arrangements through time.” (DeMers, 2002, pg. 1)

The use of GIS to model both suitable habitat and develop potential migration corridors for a given species is a solvable problem. Furthermore, the development of tools to solve these problems increases the power and functionality of standard GIS software. The development of a set of Graphical User Interfaces (GUIs) that allow the user to operate the model are of value. These GUIs shift the focus of the model from a GIS model to tools that can assist in the decision making process. These tools allow the user to implement and run SPEEDGOAT without the need for extensive GIS background. Thus SPEEDGOAT can effectively enable a wildlife biologist or other user to focus their time and efforts on management of pronghorn, and not the nuances of running a complicated GIS model. Increased functionality must be based upon solid foundations though, as a tool is only valuable if the development of that tool is based upon the best practice strategies for the field and geographic area in which it is designed and being applied.

A typical modeling process will start with a known objective, which maps to the final output of the model, and then work backwards to determine what data and processes are important. This strategy serves to ensure that the final output of a model will be an accurate abstraction of the environment in which the model was conceived to address, rather than the being an output determined by available data. It is also important to remember that the best models are parsimonious and get correct results with the least amount of computation. The more parse the model; the less error propagation occurs throughout the model (DeMers, 2002).

The representation and format a model will follow are also pertinent to the overall process. There are clearly advantages and disadvantages to both raster and vector schemes. However, since the goal for SPEEDGOAT was to create both a pronghorn habitat suitability model as well as a potential migration path tool the raster format is most appropriate. Additionally, the functionality of continuous surfaces and the ability GIS software has to manipulate those surfaces make a raster schema more favorable. The benefits of raster modeling make it the clear choice; however issues of scale and accuracy must be accounted for to ensure that each data set is a suitable abstraction of reality (DeMers, 2002).

Model:

The first phase of this project was to develop a model that could accurately predict suitable pronghorn habitat for the entire state of Wyoming. A final model is generally an assemblage of key elements; however it can be separated into smaller components and sub-models to speed the process and ensure that each phase is working properly before it is incorporated into the main model. The SPEEDGOAT model is comprised of four sub-models, each of which produced an index that was used in the final model. These indices were: 1) barriers, 2) terrain, 3) vegetation, and 4) water (refer to table 1). Each index was a combination of several different variables and processes as documented below.

The barriers sub-model was created to introduce a layer that would be a deterrent to pronghorn into SPEEDGOAT. This sub-model was developed by combining the fences, major roads, and railroads data. During this process, each component was weighted according to the importance it has in the sub-model. Both railroads and major roads are proxy indicators of fences; thus all three variables were weighted equally in the model. For most components in the model this would have been the final step, however barriers restrict pronghorn habitat, as they fracture habitat connectivity; thus the final index was reclassified with a value of 1 indicating areas where no barrier was present and a value of 0 where a barrier did occur.

The terrain sub-model was created to introduce the pronghorn requirements with respect to topography for the SPEEDGOAT model. The first variable in the sub-model being a classification of a slope layer, which is easily created from a DEM layer using ArcGIS's spatial analyst extension. The other key component to the terrain sub-model was a focal variety analysis. The focal variety layer was then weighted at 85 percent of the slope layer, since terrain variations are only viable for pronghorn if the slope is suitable. Finally they were merged and the entire sub-model output was standardized to a range of values between 0 and 1.

The vegetation sub-model was designed to replicate areas in the state that would provide suitable forage and vegetation for pronghorn. The vegetation sub-model closely mimics the pattern for the terrain sub-model and has two components. The first is a reclassification of the vegetation (landcover) layer which isolates vegetation that has been correlated with pronghorn usage. The second was again a focal variety layer which established areas where micro-habitats exist. Finally, the layers were combined using a weighting schema identical to the terrain sub-model.

A sub-model to create a layer quantifying distance to known water sources was the final sub-model created to use as an input into the SPEEDGOAT model. The water sub-model was actually fairly simple in design. It is a combination of a series of water buffers. Each buffer, 4.5 kilometers and 6.5 kilometers, were weighted in a schema where the closer to a known water source was the closer the value was to 1. After each was weighted they were combined, and places in the state that weren't within the 6.5 km buffer of a known water source were given a weight of 0, as Yoakum et al. (1996) clearly shows that pronghorn located themselves near water sources.

Snow is an important variable that influences Pronghorn; however an extensive search of available data revealed that no suitable snowpack layers exist. Furthermore the possibility of developing a snowpack layer or model was explored, but the size and scope of such a project was not feasible for this study. Additionally, the final model seems to be accounting for areas that would be classified poorly based snow.

Once each of the sub-models was created, executed, and validated for proper functionality, all were combined into the final SPEEDGOAT model using simple additive weighting (Malczewski, 1999). Just like with the sub-models, the model needed to be repeated several times to hone in on the most appropriate weights for each variable. The final weights are indicated by Table 2.

Sub-models	Weights
Barrier index	0.10
Terrain index	0.75
Vegetation index	0.95
Water index	0.50

Table 2: Final SPEEDGOAT Sub-model Weights

After each index was appropriately weighted, all were combined and the final output was standardized, by dividing the sum of the weights by the total weight. Thus the final SPEEDGOAT output has values ranging from 0 to 1. The final step in this process was to develop a classification scheme that would accurately separate habitat into categories of good, fair and poor. Several different standard and custom classification methods were tested, and in

the end the best representation was acquired by using the ranking assigned by ArcGIS Jenks Natural Breaks classification method with 3 different classes.

Potential Migration Paths:

The second phase of this research focused on the use of least cost path analyses to identify the longest prospective pronghorn migration corridors within the state of Wyoming. These migration paths were created using a reclassification of the SPEEDGOAT model output in which habitat quality was equated to pronghorn movement cost (Frank et al., 1998). Additionally, pronghorn seasonal range data collected by the Wyoming Game and Fish Department (WGFD) was used to determine the boundaries for each migration path. The WGFD breaks Wyoming's pronghorn population up into herd units based on the approximate boundaries that any pronghorn within that region may be expected. Once the approximate extent of any herd is known, a seasonal range layer can be produced.

There are approximately fifty recorded pronghorn herds within the state of Wyoming (Wyoming Game and Fish Commission, 2005). The large number of herds present within the state necessitated an automated solution for migration path creation. Additionally, the solution implemented a methodology to calculate maximum length corridors by using Euclidean distances to determine the furthest points apart for any given pronghorn herd. These points were extracted and used for the starting and ending locations for the least cost migration path.

Model Usability:

The final stage of the project was to create two graphical user interfaces (GUIs) that could harness the full capability of SPEEDGOAT and the associated potential migration tool. These GUIs can assist users in making informed pronghorn management decisions. The GUIs require no specialized GIS knowledge to implement SPEEDGOAT, and also allow for model adaptability. Too often, models are created for a specific task, and only function with a specific set of requirements and variables. However, GIS data, scientific knowledge, and further research are occurring continually, thus the SPEEDGOAT GUI was designed to allow incorporation of new data as it becomes available.

The purpose of the SPEEDGOAT GUI (Figure 1) was to simplify the model in a way that would allow for someone like a wildlife biologist could execute the model and also allow for multiple scenario trials. First the GUI needed drive the model based upon a set of user defined choices, and second to allow for quick and easy model replication. Thus the GUI was developed using Visual Basic for Applications (VBA) within the ArcGIS software was developed. This interface was developed to allow a user full model access and functionality, without exposure to the nuances of the programming and code language details. It allows the user to choose which data sub-models, including sub-models not used in the original model, to base the SPEEDGOAT output upon. Furthermore, the interface allows a user to define the relative weight each sub-model has within SPEEDGOAT. Upon successful population of the GUI's fields and options, the model can be executed. In essence, the run command actually compiles a text file containing the model scenario, and then sends the text file to another set of Code. The other code, which was developed using Python, then grabs the needed information from the compiled text file and runs the model based upon that data.

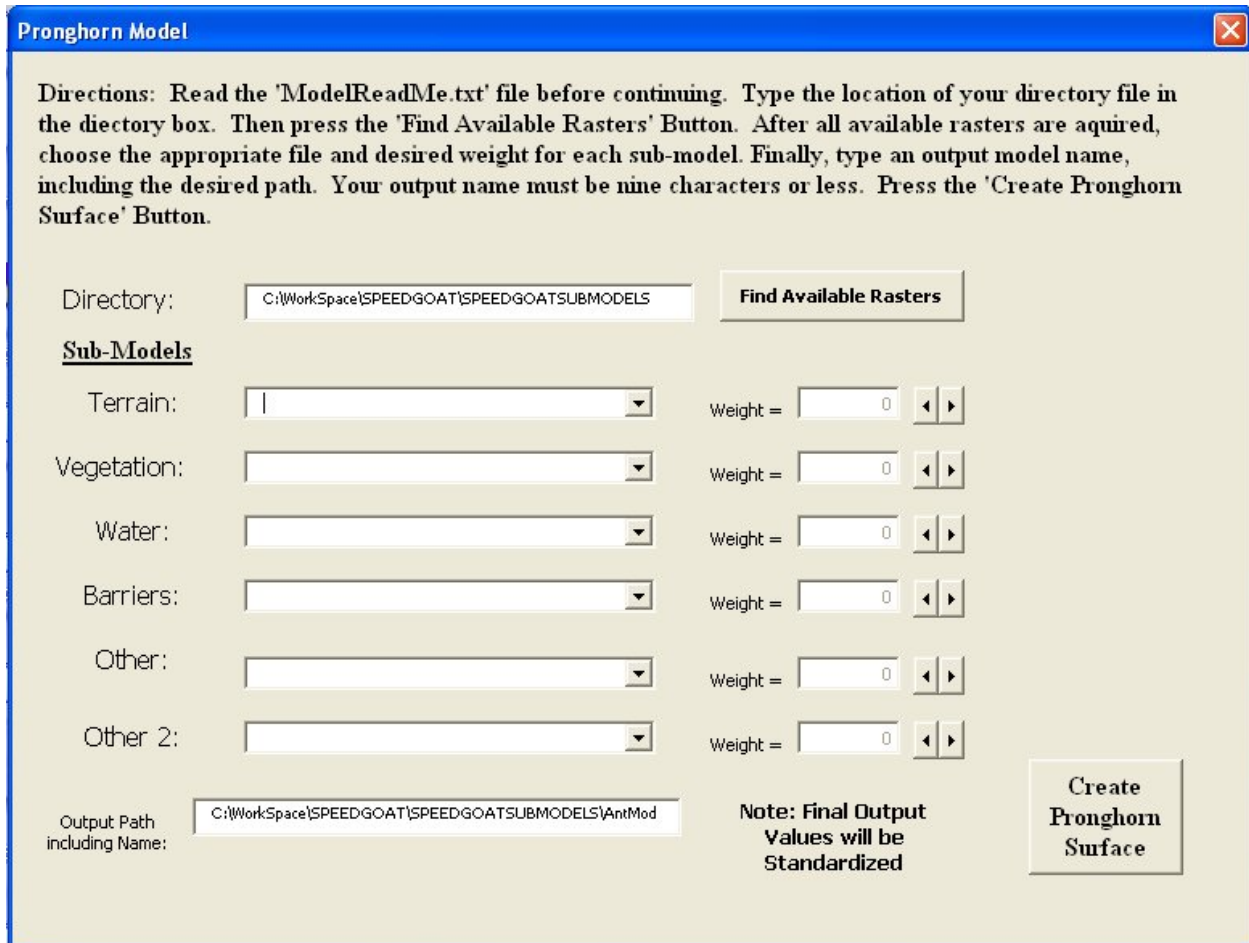


Figure 1: SPEEDGOAT GUI

Once an output is created from SPEEDGOAT, a second tool enables the calculation of probable migration paths (Figure 2). The code developed to create the original migration path was modified to allow a user to determine the course of the analysis based upon the choice of seasonal range polygons, weighted reclassification of a given SPEEDGOAT output, and a list of the particular pronghorn herds. This allows a user to confine the tool to a particular herd(s), allowing for evaluation of different management techniques in different locations. Additionally, by combining SPEEDGOAT model outputs with migration analysis, a user can compare different scenarios and how each may effect pronghorn movement. The addition of the potential migration paths GUI, takes the SPEEDGOAT modeling approach one step further. Many habitat suitability models have been created using GIS; however the addition of a tool that can predict potential movement corridors for a species adds another dimension to the species management capabilities of SPEEDGOAT. The migration path tool offers the user further management decision support. In addition to SPEEDGOAT's determination of suitable habitat, the potential migration path tool offers a plausible pronghorn migration route across a given landscape.

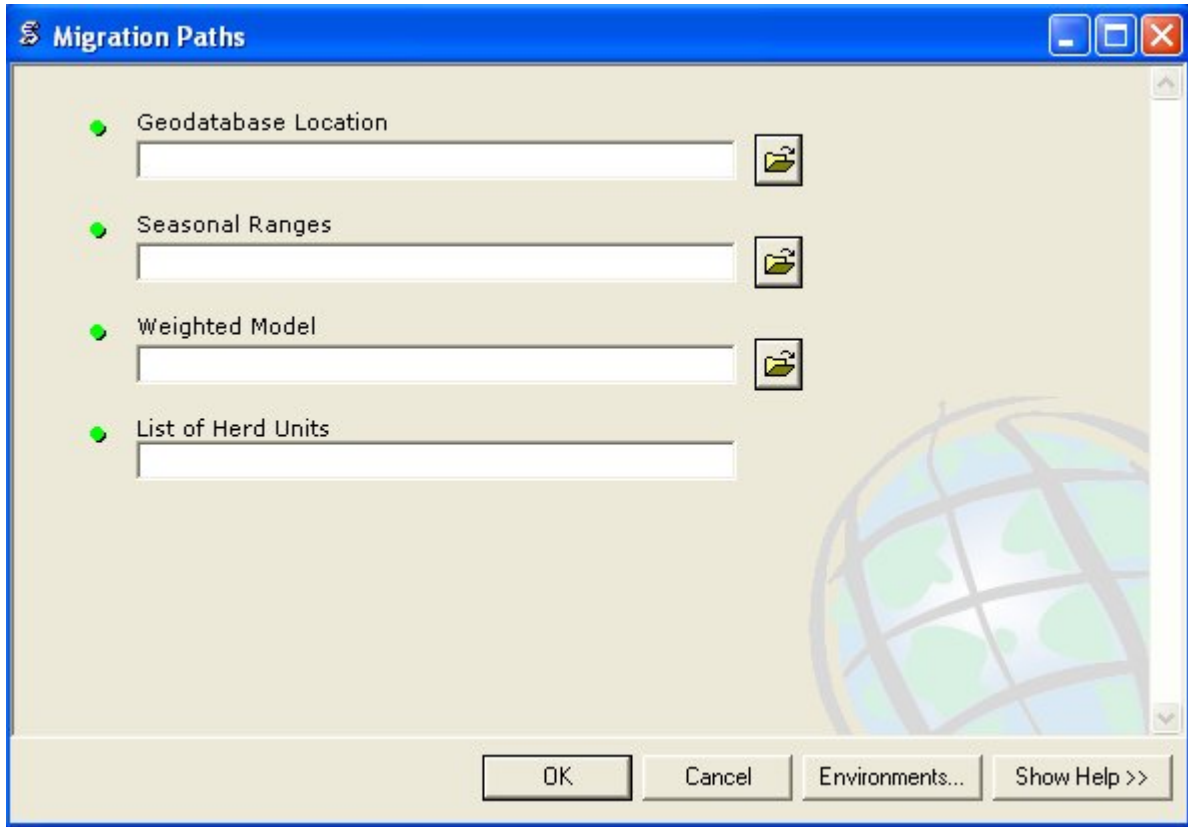


Figure 2: Potential Migration Paths GUI

Discussion and Outlook

The development of SPEEDGOAT offers a new tool to users in the pronghorn management decision making process, however accurate results are crucial to ensure sound decisions are made. Two basic chi-square analyses were used as model verification, and both indicate that SPEEDGOAT does function accurately. The first analysis compared actual pronghorn locations in western Wyoming as reported by Sawyer et al (2005) to the final SPEEDGOAT output. An eight km buffer was established around the extent of the entire pronghorn dataset, thus allowing for a regionalized comparison of actual pronghorn locations to SPEEDGOAT. Approximately 900 pronghorn locations were examined via the first chi-square analysis. To further validate the original chi-square analysis, a second one was preformed using pronghorn locations as reported by Sheldon (2005). Using methods similar to those documented above, the second chi-square was based upon over 2000 pronghorn locations. The second dataset was not examined or utilized during the development of SPEEDGOAT, rather it was treated as a hold-back data set. This approach further validates the model as the data set is completely independent from the model and was used strictly for final model validation. The results of the analyses are illustrated in Table 3 below.

Dataset	# of Locations	Chi-Squared Value	P-Value
Lindsey et al. (2005)	889	270	2.34377E-59
Sheldon (2005)	2106	266	1.42132E-58

Table 3: Chi-Square Analyses

As Table 3 shows, both chi-squared analyses returned p-values near 0. These results indicate that pronghorn are not randomly distributed across a region, and that habitat does influence where they are. Additionally, these results suggest that SPEEDGOAT is effectively predicting areas of suitable habitat for pronghorn within Wyoming.

The longest potential migration path for each pronghorn herd in the state was established using the python code documented in the methods section of this paper. Since the potential migration paths are created from a weighted output of the SPEEDGOAT model, the path is directly tied to the user's perception and needs. This technique allows the user to see what areas are crucial to pronghorn movements for any given scenario. Although, these paths cannot be construed as actual pronghorn migration corridors, they can serve as a valuable tool to support the decision making process. According to Frank et al. (1998), animal energetics dictates how specific animals move across a landscape. Specifically a particular animal or species will choose to travel along the least cost route they can find; where cost is a function of the species needed habitat requirements. Each potential migration route is a representation of the most economical route a pronghorn could travel across the longest stretch of its home range, based upon the user's manipulation of SPEEDGOAT. Thus the potential migration path tool enhances the decision support process capabilities of SPEEDGOAT and provides users with further understanding of how effects to pronghorn habitat may affect the species.

The development of a working SPEEDGOAT model and associated migration path creation tool was a key component of this project; however the value of both tools increased with the development of user-friendly interfaces. The objective of these GUIs is to allow the user to focus on pronghorn management decisions, thus they were designed to allow the "interface between the human and the computer seamless" (Jansen, 1998). The development of the SPEEDGOAT interface was complex, as it used a combination of both Visual Basic and Python code to execute. All the code executes behind the scenes based upon the choices the user enters into the self-explanatory user-interface. The migration path tool interface allows the user to define certain parameters to focus the output to a specific region(s) thus providing the user with a tool that can provide information and analysis specific to his/her needs.

Conclusions

The development of SPEEDGOAT and the GUI interfaces came from the pronghorn management users need for a tool that could harness the power of GIS technology, and simplify it to allow a user to make informative management decisions.

SPEEDGOAT can provide someone such as a wildlife biologist with new information based upon his/her knowledge of pronghorn species. This enables a user the ability to use the best scientific practices for pronghorn in conjunction with a tool that provides not only a visual output that can be duplicated; but additionally, allows the user to execute and compare multiple scenarios.

The potential migration corridor tool further enhances the capabilities of SPEEDGOAT by allowing a user to see what how pronghorn may choose to navigate across a habitat based upon a certain set of criteria or habitat changes. Its capabilities also allow for multiple scenario comparison. Although the concepts behind habitat modeling and animal energetics are well known, the potential information that can be obtained when the two are combined can serve to further assist in habitat or species management.

Furthermore, the two GUIs allow a user to easily access the capabilities of the technology without being an experienced GIS specialist. A user-friendly interface allows someone with

limited experience to access the power of GIS technology in a way that is efficient. This allows the user to focus on his/her main objective, versus spending time to learn new technology. Thus SPEEDGOAT, is more than the combination of specific GIS capabilities, it has the ability to empower a user with a new tool that can ultimately assist in managing pronghorn in a way that will benefit both the species and the state of Wyoming's dependence upon it.

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