A Pilot Project to Visualize Kentucky's Modeled Vertebrate Habitat Change

Brian D. Lee[1], Collin D. Linebach[1]

Introduction

Habitat loss and fragmentation are often cited as two of the most important reasons for the decline of biological diversity around the world (Meffe and Carroll 1994). It is an appealing idea to conserve the most biodiversity by maintaining examples of all the natural communities. Several approaches to the spatial identification of biodiversity have been described over the years (Kirkpatrick 1983; Margules et al. 1988; Pressey and Nicholls 1989; Nicholls and Margules 1993). It is important to recognize that a gap analysis is a process to identify landscape areas for potential conservation but does not actually apply conservation measures. The landscape is a changing resource and understanding the changes in relationship to gap analysis is important for planning and management. These changes have ramifications for vertebrate biodiversity as the landscape becomes more fragmented and/or is converted to urbanized or agricultural uses. Identifying and visualizing geographic losses and/or additions to modeled habitat using gap analysis for multiple species simultaneously is potentially valuable for managing vertebrate resources. The goal of this pilot project was to explore an analysis and visualization approach that could aid in understanding modeled habitat dynamics. Specifically, the project was to develop an approach to visualizing habitat, stability or change, at two distinct times across multiple vertebrate species simultaneously using the Environmental Monitoring and Assessment Program (EMAP) hexagons (White et al. 1992) as the landscape unit of analysis. Ultimately, this project has the potential of helping people make decisions about the utilization of limited financial and technical resources for vertebrate species.

Using concepts developed through GAP (Gap Analysis Program 2000; Scott et al. 1993), and specifically the Kentucky GAP Analysis Final Report (2003), this pilot project explored the opportunities and constraints of quantifying terrestrial habitat for several groups of vertebrate species. This effort builds on expertise, methods, and data of the original Kentucky GAP Project as well as utilizing expertise developed during GAP efforts in several states. This work extends the original Kentucky GAP Project by incorporating more recent statewide land cover data and advancements in computing software/hardware technologies while continuing to use EMAP hexagons.

Project Description

When the original Kentucky GAP Project was finalized in 2003, several future needs were identified. The Kentucky GAP team encouraged research that would apply and expand upon the original effort. For example, the results were partially incomplete without a means to compare changes over time according to the final report (Kentucky GAP Analysis Final Report 2003). The original Kentucky GAP did not explicitly include the capability to incorporate temporal landscape change. A second generation of Kentucky GAP that used more current data and explicitly incorporated monitoring of temporal shifts in biodiversity was recommended. The methods developed during this pilot project can potentially be included in land use planning, statewide and regional biodiversity planning, and county based land use planning.

Land cover data based on 1992 Landsat Thematic Mapper (TM) satellite imagery was the most recent available for the original Kentucky GAP Project completed in July 2003. The original Kentucky GAP Project was performed using TM imagery that is now more than 16 years old. Wildlife species distribution maps used in the original Kentucky GAP Project also are outdated. Data and results generated from the original Kentucky GAP have been valuable to state wildlife management efforts. Because of advancements in geographic information systems (GIS) and more current datasets, there was an opportunity to reapply the original Kentucky GAP Project models to visualize how modeled habitat has or has not changed from 2001 to 2005. The approach described in this paper allows for the visualization of temporal and spatial dynamics.

Today, land cover datasets available for Kentucky include the National Land Cover Data (NLCD) 2001 (Homer et al. 2004; Homer et al. 2007) and a compatible dataset

[1] Department of Landscape Architecture, College of Agriculture, University of Kentucky, Lexington, KY.

classifying statewide land cover in 2005 (Kentucky Division of Geographic Information 2007). The 2005 Kentucky Land Cover Change Detection 2001/2005 has Anderson Level II categorization. This dataset produced for the Commonwealth of Kentucky, for the 2005 era, is part one of a two-part dataset that explicitly focused on land cover change detection analysis. The second part of the dataset is a change/no change mask. The goal of the 2005 update project was to provide the Commonwealth of Kentucky with more current and accurate land cover change information since the NLCD 2001. The change detection analysis is based on Landsat Thematic Mapper scenes from 2001 and 2005 (Kentucky Division of Geographic Information 2007). These new land cover data provided an opportunity to update modeled habitat maps. They also provided the opportunity to test for differences in amount, location, and spatial configuration of modeled habitats and to grossly characterize how terrestrial vertebrate species habitat was or was not changing across the state by the EMAP hexagonal grid (White et al. 1992; U.S. Environmental Protection Agency 2008).

Model Development

This pilot project compared standard GAP vertebrate species distribution models from two times to measure changes in habitat. This project generally followed the species model development that was done for the original Kentucky GAP completed in 2003. The habitat characterization, known ranges, and methods were all reviewed by experts for the original Kentucky GAP Project at that time and accepted by the national GAP Analysis Program. By utilizing the original Kentucky GAP approach, comparisons can be made utilizing the newer NLCD 2001 for Kentucky (Figure 1) and the 2005 Kentucky Land Cover Change Detection product (Figure 2) to visualize modeled landscape scale habitat changes across the state for multiple species simultaneously.

Rather than the 365 terrestrial vertebrate species modeled by the original Kentucky GAP Project, this pilot project used a forest dependent species subset of five animals. The species selected were eastern small-footed myotis (*Myotis*

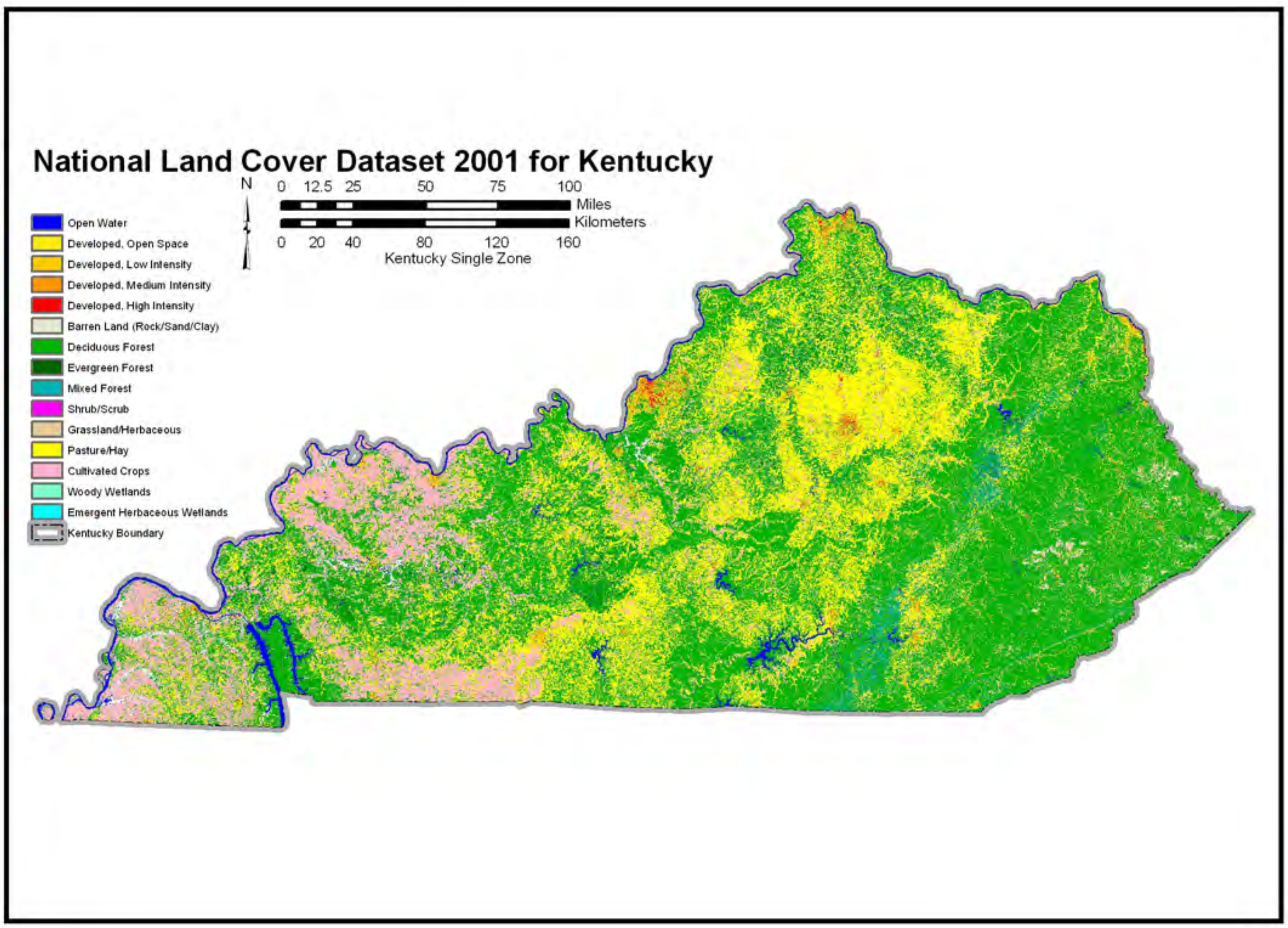


Figure 1. National Land Cover Dataset 2001 for Kentucky.

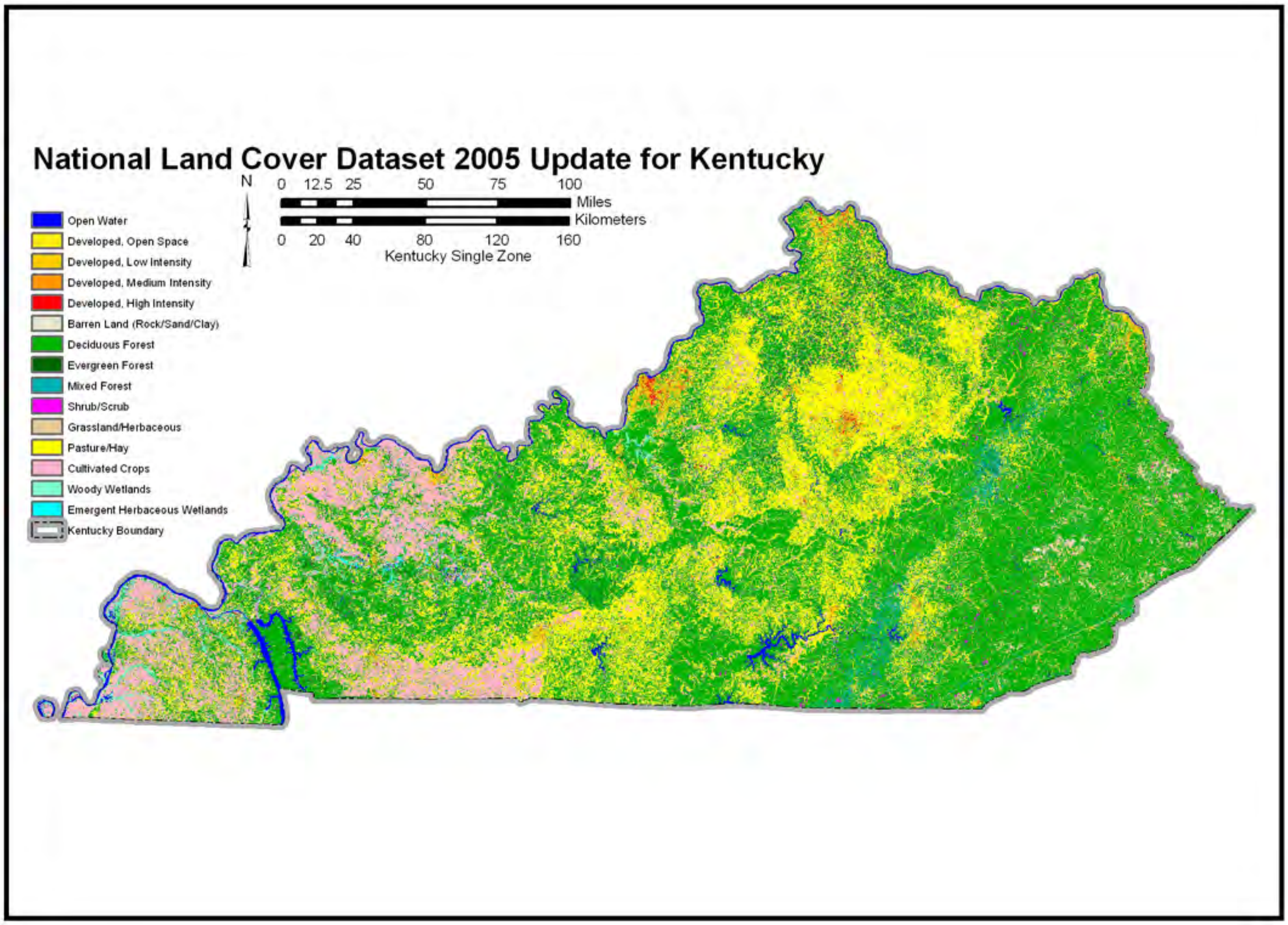


Figure 2. 2005 update to the National Land Cover Dataset 2001 for Kentucky.

leibii), black bear (*Ursus americanus*), eastern spotted skunk (*Spilogale putorius*), Kentucky Warbler (*Oporornis formosus*), and Red-headed Woodpecker (*Melanerpes erythrocephalus*). The species selection was performed by an expert at the Kentucky Department of Fish and Wildlife Resources who was also instrumental in the completion of the original Kentucky GAP Project (2003). A foundation for the expert's species selection was the Kentucky Department of Fish and Wildlife Resources' Wildlife Action Plan (Kentucky's Comprehensive Wildlife Conservation Strategy 2005). The species models were executed using the same procedures for 2001 and 2005 land cover data, which allowed for habitat analysis at the two points in time across the state. The objective was to make comparative analyses of the habitat changes or stability between the two snapshots of land cover. A generalized workflow diagram (Figure 3) shows five major process steps of this approach.

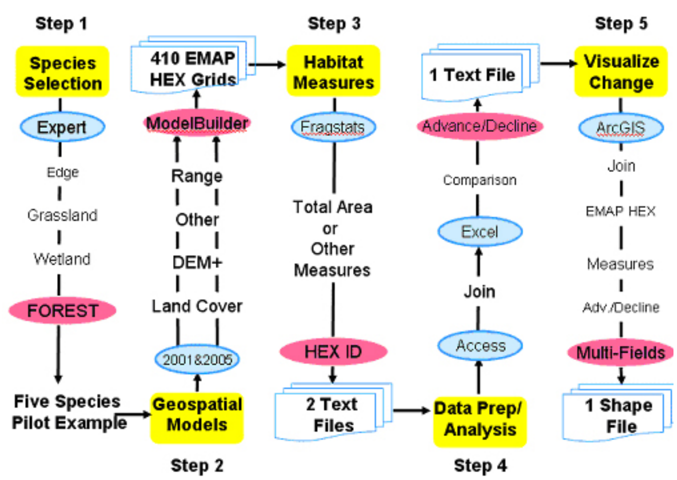


Figure 3. The generalized workflow diagram of habitat modeling and change visualization process used in this project.

The advancement in GIS technology that helped complete this project was the ModelBuilder framework of the Environmental Systems Research Institute's (ESRI) ArcGIS v. 9.2 (SP 4) (ARC/INFO License) (ESRI, Inc. 2007) software package. ModelBuilder provided a graphical framework for designing and implementing the species models. There are several ways in which to assemble the data and processes in ModelBuilder. In this project, a separate ModelBuilder model was created for each species that included the 2001 and 2005 land cover data previously described. An alternative method considered was to develop one ModelBuilder model for each grouping of species for both timeframes. This latter approach did not appear to provide the flexibility to easily consider an individual species efficiently. In addition, as the complexity of the ModelBuilder model increased, computing performance tended to decrease which slowed species model development.

ArcGIS v. 9.2 has the capacity to batch process the models. This feature was particularly useful for repeatedly extracting habitat distributions within many standard areas such as watersheds, the United States Geological Survey 1:24,000 quadrangles, or the EMAP hexagons as was used in this project. In this project, the modeled distribution for 2001 and 2005 were extracted by each hexagon of the hexagonal grid. For Kentucky, 205 hexagons cover the state (Figure 4); this process resulted in 410 ESRI GRID files for each species for subsequent analysis using Microsoft Access (Figure 3 – top of Step 2). An ESRI GRID file is an Environmental Systems Research Institute format for storing raster data defining geographic space and is referred to as GRID in the remainder of this paper. During this pilot project's development, when the batch process capability was utilized, computing performance decreased substantially. Therefore, a separate ModelBuilder model was used exclusively for the purpose of habitat extraction by the EMAP hexagons. This allowed personnel resources to be used more efficiently.

Fragstats v. 3.3 Build 5 was used to analyze each extracted hexagonal GRID for each species at each point in time. Fragstats is a spatial pattern analysis program for

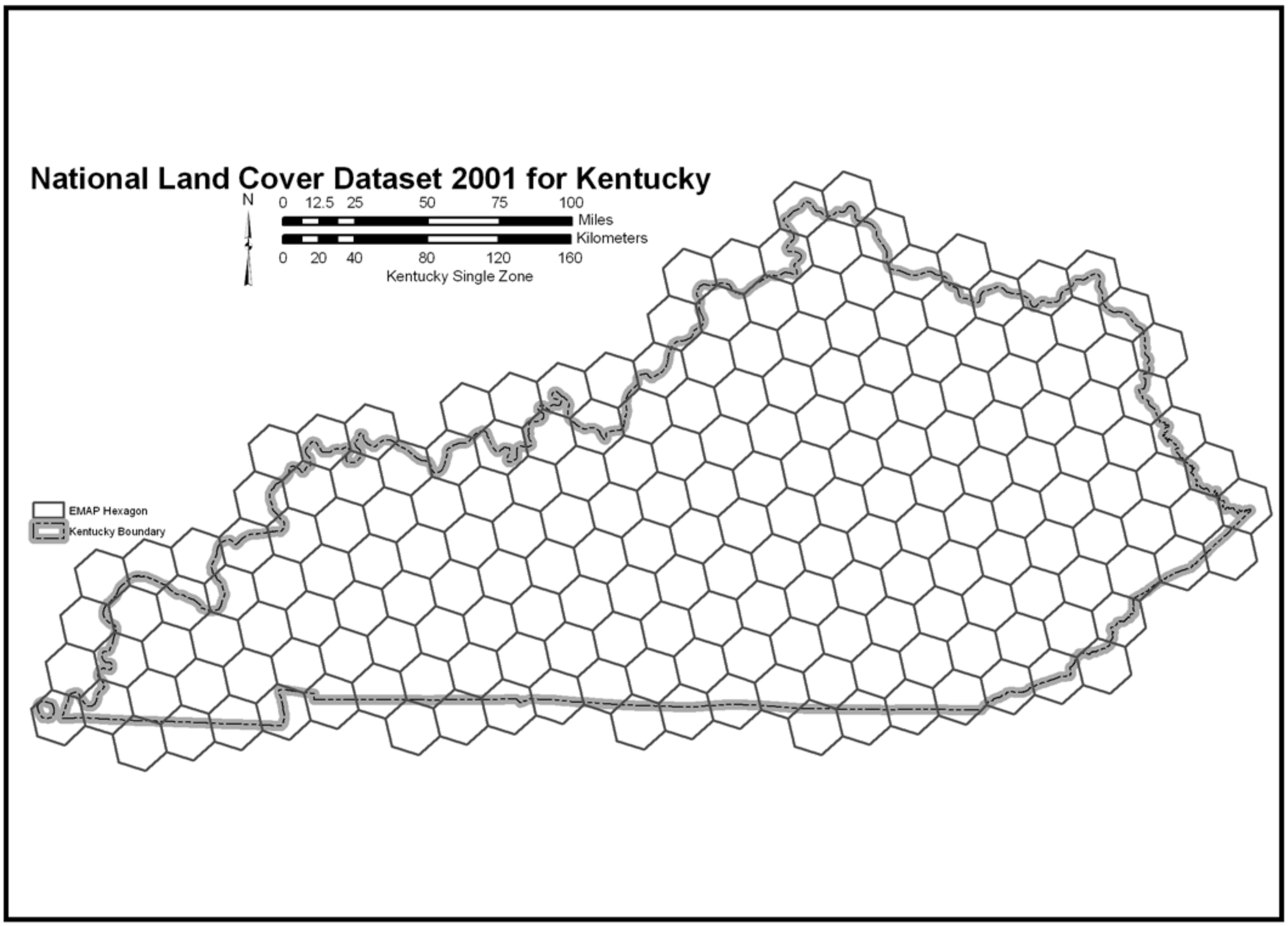
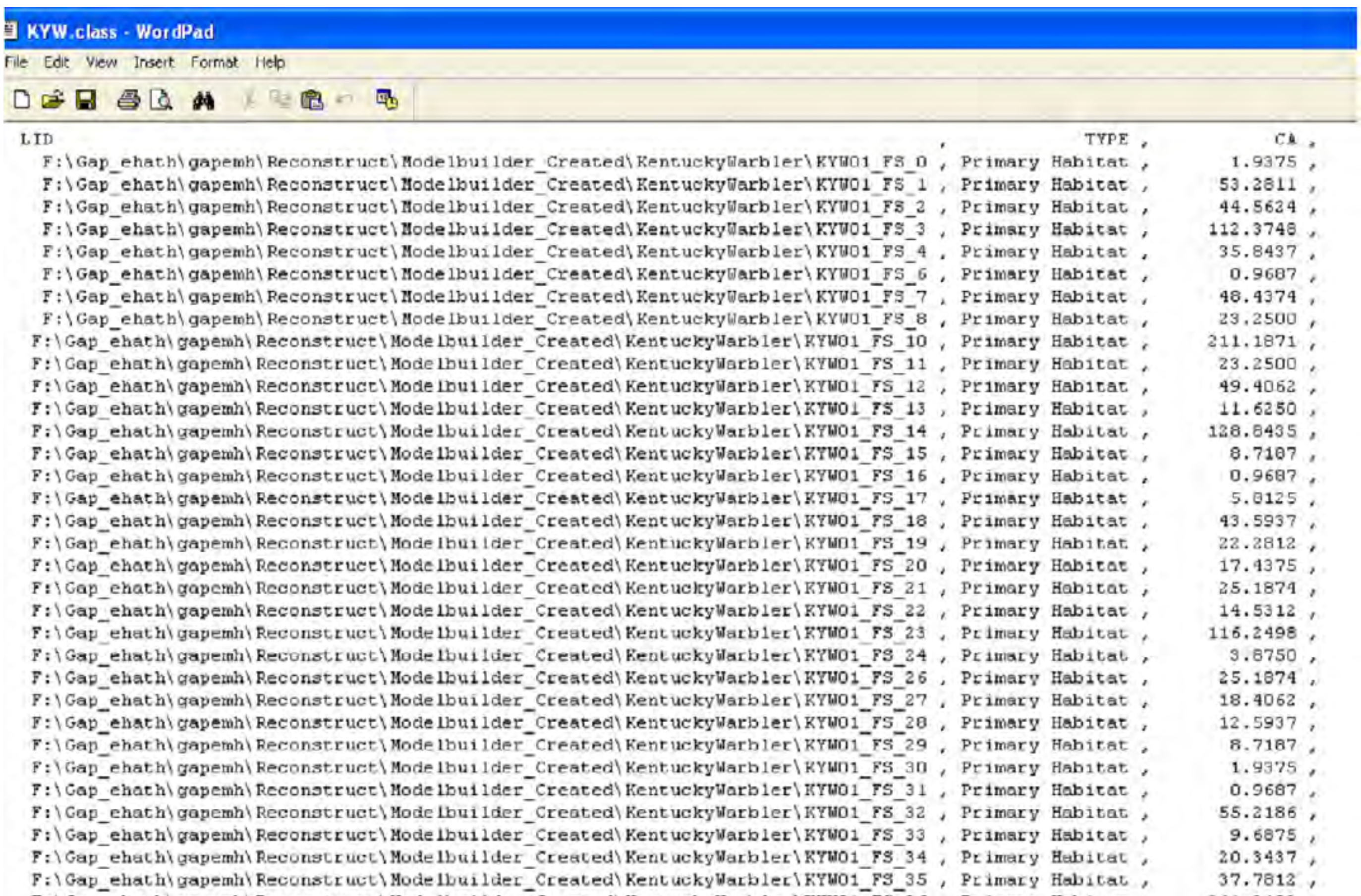


Figure 4. 2005 update to EMAP Hexagons from the National Land Cover Dataset 2001 for Kentucky.

categorical maps (McGarigal et al. 2002). Fragstats has the ability to quantify the area, extent, and spatial configuration of habitat within an area. In this project, each hexagonal GRID extracted was analyzed. Dozens of habitat metrics are capable of being reported by Fragstats including total area, percent of landscape, number of patches, mean/median patch area, nearest neighbor, etc. It is important to note that choosing the appropriate metric(s) to describe habitat is potentially species dependent. McGarigal et al. (2002) places responsibility on the user to understand metric behavior. For the sake of simplicity in describing the general visualization process used in this paper, only the habitat area as reported by Fragstats for each hexagonal GRID was used. Specifically, the Fragstats metric used was TOTAL AREA (CA/TA). The output data from Fragstats were written to a delimited text file (Figure 5) for use in other software applications such as Microsoft Excel and Microsoft Access. Subsequently, the data were joined back to the original EMAP hexagonal grid for visualization following the data manipulation and additional analysis described in the upcoming advancing and declining section (Figure 3 – Steps 4 and 5).

An objective of this pilot project was visualizing habitat, stability or change, as measured by Fragstats metrics at 2001 and 2005 across multiple species simultaneously using the EMAP hexagon extracted habitat GRIDs. The approach used in this pilot project identified each species by each EMAP GRID as to whether it gained habitat (Advancing), lost habitat (Declining), or stayed the same as indicated by TOTAL AREA (CA/TA). Other Fragstat metrics could be used depending on species. Advancing and declining are terms that are often used to describe financial stock market performance (Fosback 1976).



LID	TYPE	CA
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_0	Primary Habitat	1.9375
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_1	Primary Habitat	53.2811
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_2	Primary Habitat	44.5624
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_3	Primary Habitat	112.3748
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_4	Primary Habitat	35.8437
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_6	Primary Habitat	0.9687
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_7	Primary Habitat	48.4374
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_8	Primary Habitat	23.2500
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_10	Primary Habitat	211.1871
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_11	Primary Habitat	23.2500
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_12	Primary Habitat	49.4062
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_13	Primary Habitat	11.6250
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_14	Primary Habitat	128.8435
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_15	Primary Habitat	8.7187
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_16	Primary Habitat	0.9687
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_17	Primary Habitat	5.8125
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_18	Primary Habitat	43.5937
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_19	Primary Habitat	22.2812
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_20	Primary Habitat	17.4375
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_21	Primary Habitat	25.1874
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_22	Primary Habitat	14.5312
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_23	Primary Habitat	116.2498
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_24	Primary Habitat	3.8750
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_26	Primary Habitat	25.1874
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_27	Primary Habitat	18.4062
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_28	Primary Habitat	12.5937
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_29	Primary Habitat	8.7187
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_30	Primary Habitat	1.9375
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_31	Primary Habitat	0.9687
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F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_33	Primary Habitat	9.6875
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_34	Primary Habitat	20.3437
F:\Gap_ehath\gapemh\Reconstruct\Modelbuilder_Created\KentuckyWarbler\KYW01_FS_35	Primary Habitat	37.7812

Figure 5. Fragstats delimited output text file of metric values by hexagon for 2001 and 2005.

Advancing and Declining Background

Borrowing ideas from broad scale stock market characterization allowed for visualizing modeled habitat changes. The number of stocks that have advanced, declined, or remained unchanged is commonly reported by most news organizations that include financial news as part of their regular coverage. To set the context of using broad scale stock market analysis approaches to characterizing and subsequently visualizing modeled habitat over time, it is important to review some essential points. Fosback (1976) provides detailed examples and discussions of the rationale, limitations, and attributes of using advancing and declining stocks to characterize overall stock market performance. In stock market terms, using price highs and lows or counts of stocks going up or down in price is referred to as market breath analysis (Fosback 1976). If most stocks are increasing in price, the market is generally thought of as having good breath or gaining momentum. If most stocks are declining in price, then the market is thought of as having bad breath or losing momentum (Fosback 1976).

Species Modeled Habitat Advancers and Decliners

The approach described in this paper helps paint a geographic picture of vertebrate species habitat stability or change across the state without relying on direct cell-to-cell comparison of Landsat scenes at two points in time. At this point in the process, there are modeled habitat GRIDS for each species across the state for 2001 and 2005. Once individual species habitat models are completed and EMAP hexagon GRIDS extracted of modeled habitat (Figure 3 – bottom of Step 3), the tabular calculations are completed based on the two observation times (Figure 3 – Steps 4 and 5) resulting in the number of species where total area advanced (Figure 6) or declined (Figure 7). These observations of the models were summed and mapped following a tabular join by hexagon identification code.

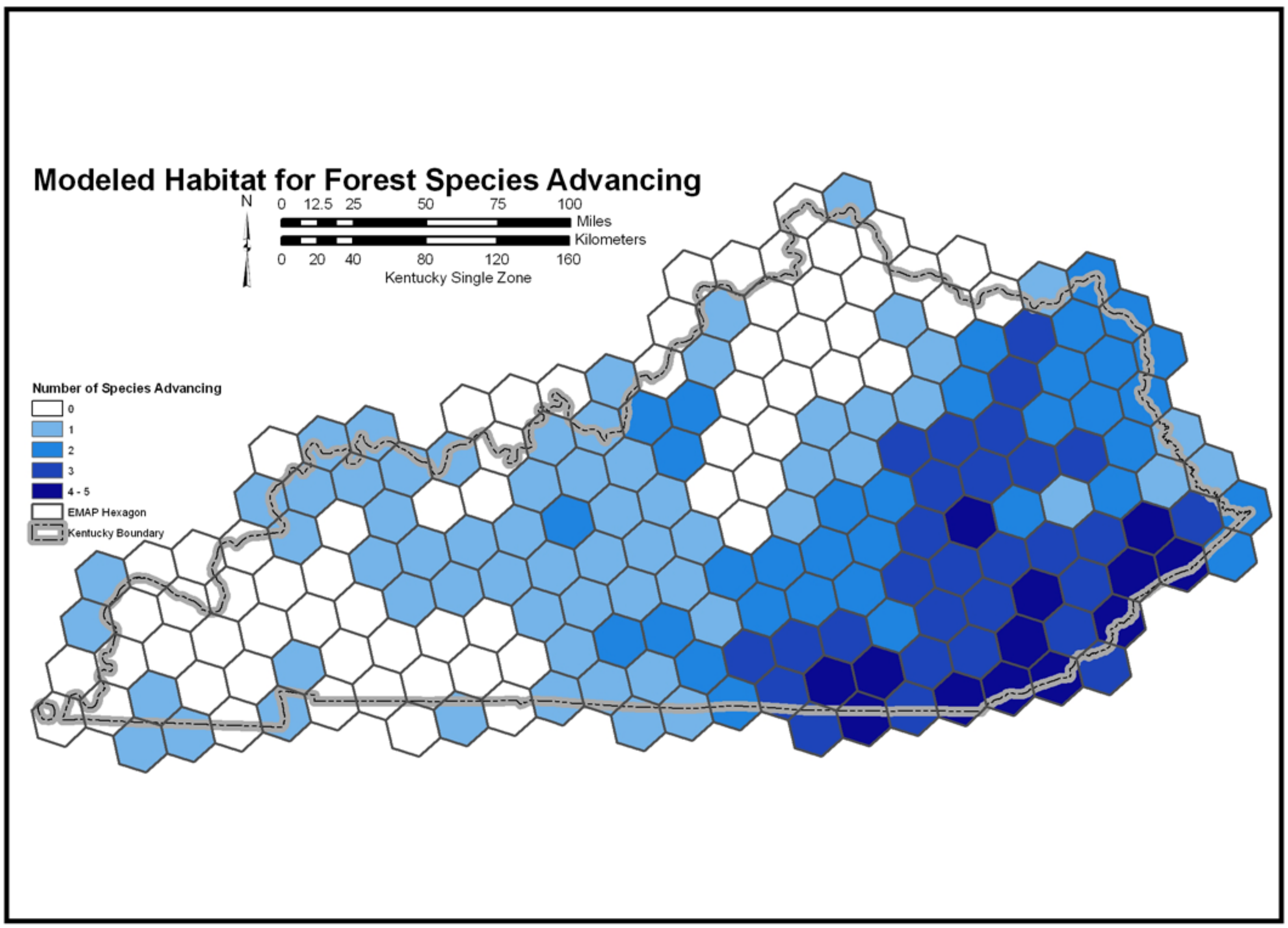

Figure 6. Location and number of species with modeled habitat advances between 2001 and 2005 by hexagon for Kentucky.

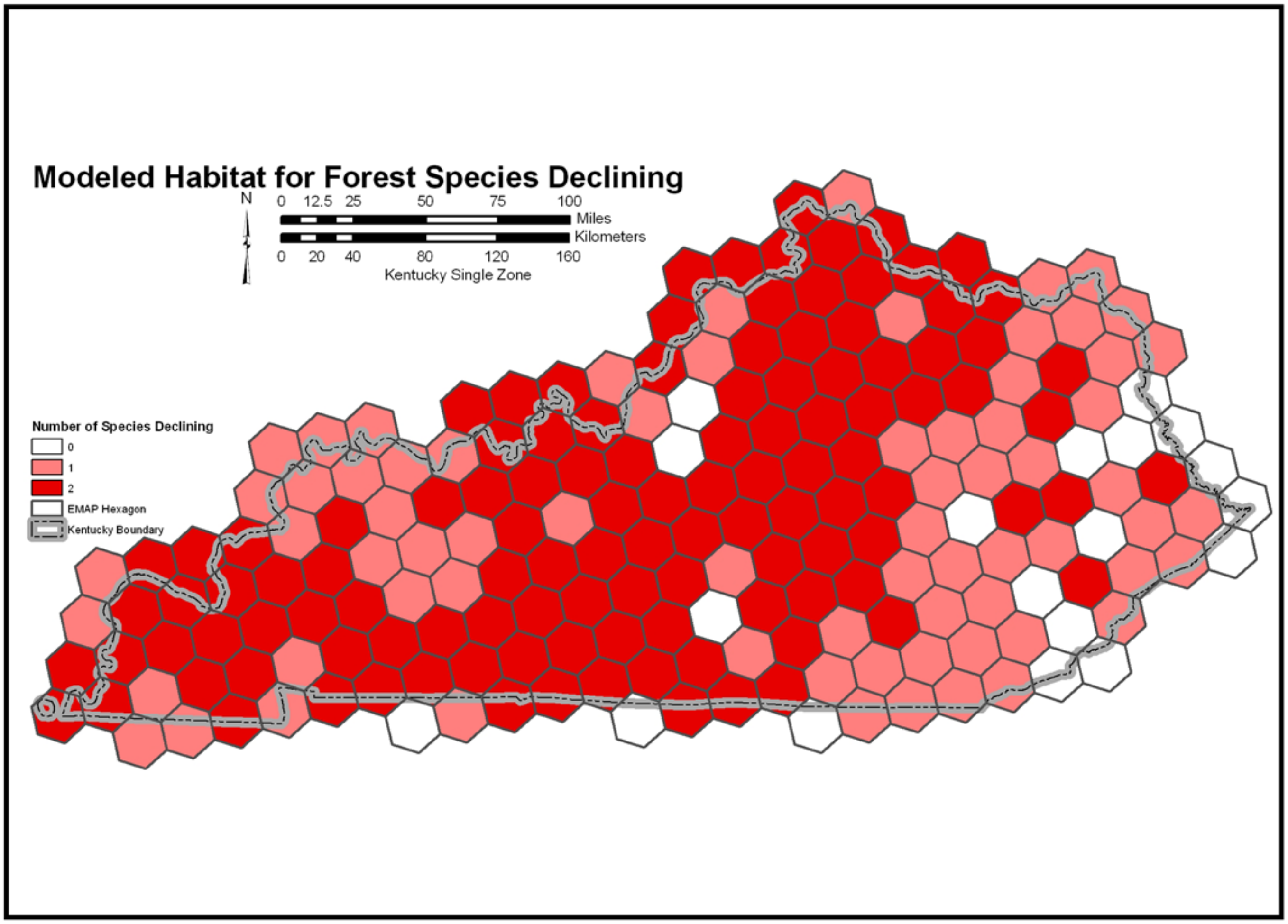

Figure 7. Location and number of species that had modeled habitat declines between 2001 and 2005 by hexagon for Kentucky.

The analysis of Advancers to Decliners or A/D Ratio is considered an indicator of market movement as a whole when discussing stock markets. When the ratio is low, it indicates that the market is moving down. When the ratio is high, it indicates the market is moving up. In the context of this paper, the A/D Ratio is the ratio between advancing modeled habitats and declining habitats for each species in the EMAP heaxagon and was calculated as follows:

A/D Ratio = number of species habitats Advancing / number of species habitats Declining

In wildlife habitat terms, a value of three means that three times as many species modeled habitats advanced as to species modeled habitats declined. Any value less than one means more species modeled habitats declined than species modeled habitats advanced (Figure 8). This characterization was not thought of as the number of habitat types but as total habitat area by EMAP hexagon.

An additional way to visualize modeled habitats across the state is with the Advance–Decline Spread or A–D Spread. This is a variation on the A/D Ratio. Just as its name implies, the A–D Spread charts the difference between the number of advancing modeled habitats and declining modeled habitats in each EMAP hexagon. The formula for the A–D spread is as follows:

A–D Spread = number of species habitats Advancing – number of species habitats Declining

The A–D Spread is an oscillator that revolves around zero. The A–D Spread is interpreted much like any oscillator with overbought and oversold levels near the extremes of the chart when in the context of the stock market. In the context of this paper, when the A–D Spread crosses above zero, this means more species habitats are advancing than are declining, and vice versa.

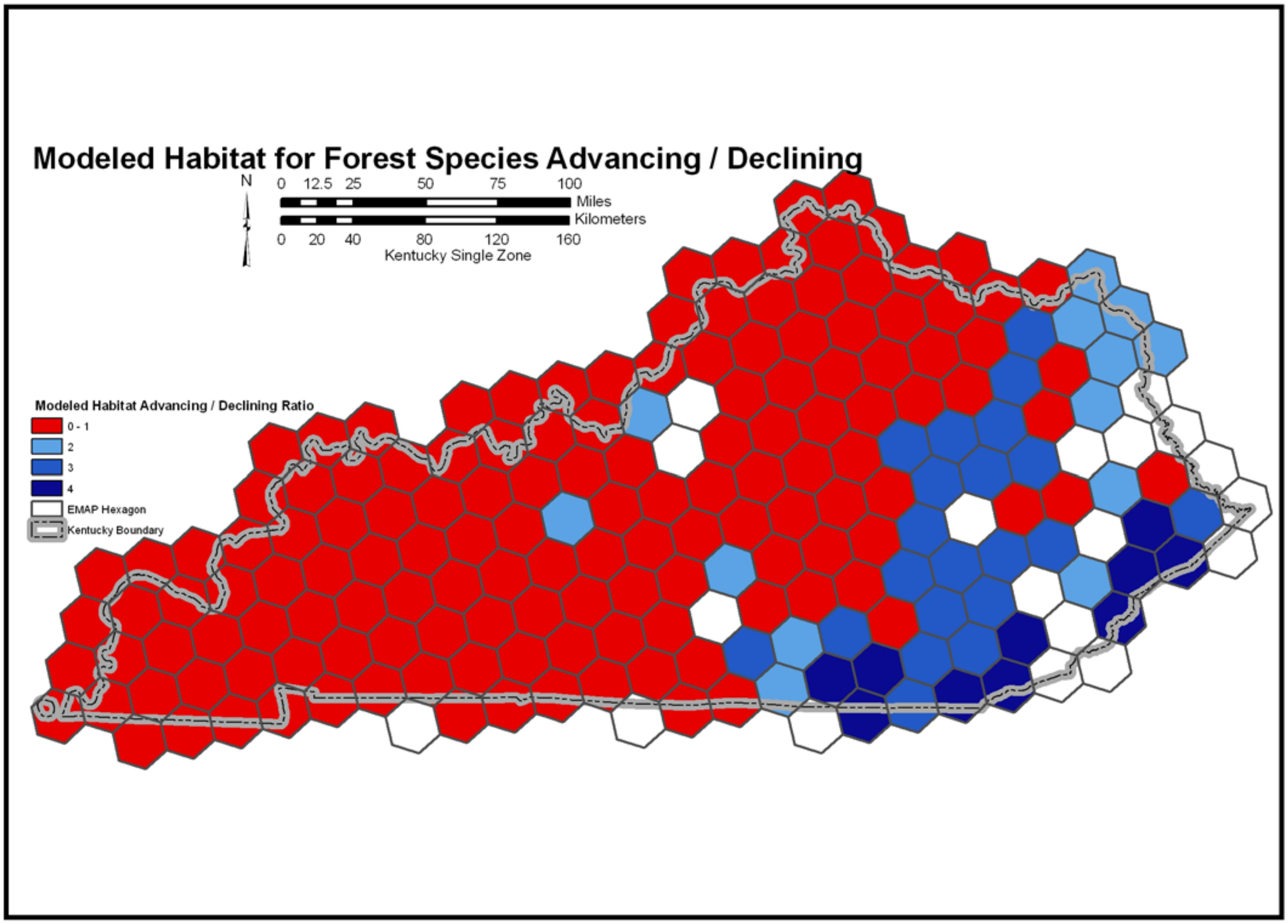

Figure 8. Location and the modeled habitat advance/decline ratio characterization by hexagon for Kentucky.

Discussion and Conclusions

There are strengths, limitations, and needed advancements to the modeling approach described in this paper. The lack of reliance on direct raster cell-to-cell modeled habitat comparisons, which can be difficult to achieve, is an advantage. Another advantage is the various metrics that can be used from Fragstats to quantitatively characterize habitat on a species-by-species decision, although only TOTAL AREA was used in this paper. Another strength is that the ModelBuilder species modeling approach allowed for relatively quick model adjustment and execution without extensive programming knowledge. For example, initially this project was going to use the 1992 and 2001 land cover data; however, the cross-walk between the two datasets was difficult to perform because the classification techniques and class definitions had changed. The comparison did not appear to work effectively upon visual inspection of the modeled habitat results. In addition, the Multi-Resolution Land Characteristics Consortium (MRLC) has cautioned users that direct comparison between 1992 and 2001 is not recommended unless the retrofit product is used (MRLC 2008). The retrofit product uses the Anderson Level I classification, which was not considered sufficient for this project's objectives. During the development of the approach described in this paper, the Commonwealth of Kentucky–Division of Geographic Information led the updating of the NLCD 2001 for Kentucky using 2005 data. The 2001/2005 update project's goal was to provide more current land cover information since the NLCD 2001 (Kentucky Division of Geographic Information 2008). Therefore, the decision to make comparisons between 2001 and 2005 modeled habitats was seen as an opportunity. Advancing and declining characterization can be performed on a variety of mapable units of analysis. EMAP hexagons were used in this paper but additional units could be used that are in keeping with data resolution capabilities. In addition, the modeled habitat characterization could be visualized by various combinations of species or specific groupings, such as only forest interior birds.

There are also some limitations of the approach and opportunities to extend the approach described in this paper. Better decision criteria thresholds for advancing/declining determination need to be established to indicate when the landscape has actually changed in a significant way. At this time, the species model development has relied exclusively on the literature, previous GAP projects, and organizational knowledge of species. The models used in this paper have not been validated with currently known species field occurrences. One approach for improving models could be based on the work of Laurent et al. (2006; 2007), particularly with respect to species model validation of Laurent et al. 2007. The visualization approach described in this paper depends on having individually valid species specific models.

Some geospatial ancillary data for the state are not up-to-date. For example, the state's wetlands and the GAP stewardship shapefiles are years to decades old. The Kentucky topography is believed to be markedly different today due to urbanization and mineral extraction processes; therefore, better topographical and subsequently landscape position data should be incorporated. The need to update the commonwealth's digital elevation data was identified during a 2008 statewide conference entitled "Mapping and Monitoring Land Resource Change: Bridging the Geospatial Divide" as a critical dataset to make available. The process outlined in this paper provides additional reasons to revisit and update those data. Future work will include expanding the species list to include more forest, wetland, grassland/open, or edge/mixed/early successional species before attempting an entirely revised Kentucky GAP Project. An additional opportunity exists by using an approach similar to what Pennsylvania GAP did in terms of the Regional Habitat Insecurity Index (RHII) and Leading Landscapes to identify areas of special conservation concern (Myers et al. 2000).

Biodiversity inventories can be visualized as "filters" designed to capture elements of biodiversity at various levels of organization. One approach is to employ a fine filter of rare species inventory and protection and a coarse filter of community inventory and protection (Jenkins 1985; Noss 1987). Gap analysis is a coarse filter method because it can be used to quickly and cheaply assess the other 85–90 percent of species. It is postulated that 85–90 percent of species can be protected by the coarse filter without having to inventory or plan reserves for those species individually. The approach described in this paper expands on the visualization aspects of the coarse filter with the incorporation of a temporal component.

The findings of the ongoing project are anticipated to improve the ability of planners and other management experts to determine where and by how much habitat resources are expanding, contracting, or staying the same. This approach has value for determining the allocation of limited financial and personnel resources for sustaining wildlife resources in Kentucky and potentially elsewhere. This work also has the potential to help land use planning efforts across the state by identifying critical habitat areas for use in landscape conservation planning. Using relatively few visualization products, planners and managers can discern broad scale patterns of habitat changes. By choosing different groupings of species to include in the advance/decline analysis, preliminary visualization can be used to give direction for more detailed investigations for the causes of increased or decreased habitat. This visualization approach potentially can be used as a landscape warning system of habitat change provided there is a period update to the data required in the species models.

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