IDENTIFYING PRIORITY CONSERVATION AREAS FOR GRASSLAND BIRDS IN AN AGRICULTURAL REGION (CHAMPLAIN VALLEY OF VERMONT)

Flavio Sutti, Allan Strong

ABSTRACT: Recent programs to set population goals for declining bird species have led to more explicit ties to on-the-ground conservation projects. However, conservation work often proceeds opportunistically, leading to inefficient allocation of conservation funds. This project was designed to prioritize conservation efforts on grassland bird habitat in the Champlain Valley (VT, USA). We created detailed GIS layers including landscape level factors (forest, grassland, development and roads) and patch level factors (size, management and conservation) important in grassland bird habitat selection and conservation. Integrating the GIS dataset into a multicriteria decision analysis framework, we produced maps in which grassland patches were ranked based on their quality for grassland birds and used these maps to identify priority conservation areas. The maps emphasized blocks of >50 ha of near protected areas and areas managed less intensively. Two regions were identified (Franklin and Addison counties) that have the highest quality values for grassland birds. These procedures resulted in maps that federal, state, and non-governmental land managers will use as a baseline to focus conservation efforts and can serve as a model to help researchers set priorities for land conservation in other regions.

Key Words: grassland birds, multicriteria decision analysis, conservation, Analytic Hierarchy Process

Introduction

Grassland bird populations have been facing consistent declines throughout North America (Cunningham & Johnson 2006; Herkert 1994; Perlut et al. 2008; Sauer et al. 2008; Walk & Warner 1999), with population declines >1% per year in the past 40 years (Sauer et al. 2008). At that rate of decline, the total population size would be reduced by 50% in less than 70 years. The decline of grassland birds is also particularly significant in the eastern United States where approximately 70% of these species are declining

Multiple causes have been proposed to explain the decline of grassland birds, but loss of available habitat and declining habitat quality are recognized as key elements in the decline of this guild (Bollinger et al. 1990; Cunningham 2005; Herkert 1994; Vickery et al. 1994). In the past few centuries, forest clearing for agriculture led to the expansion and increase in abundance of grassland birds in the eastern United States (Askins 1999; Norment 2002), but the intensification and mechanization of agricultural practices in recent decades are proving to have a deleterious effect on breeding success of grassland birds (Bollinger et al. 1990; Perlut et al. 2006). Due to the intensification of agricultural practices, many hayfields and pastures, might in fact function as ecological traps. Birds returning from migration select attractive and potentially suitable grassland patches in the spring, but their nests are destroyed when hayfields are cut or cows are pastured during the summer (Bollinger et al. 1990; Schlaepfer et al. 2002).

Grassland birds, especially in the Northeast, rely largely on agricultural fields and grassland patches increasingly subject to human activities. Thus, the conservation of grassland birds and their habitat is a process that unavoidably competes with the needs of society for development and maximization of agricultural activities. In the selection of priority conservation areas for grassland birds, the goal of maximizing preserved biodiversity must be considered with the goal of minimizing costs to society in order to make grassland habitat protection logistically and economically feasible (Cameron et al. 2008). Although there are several conservation programs that provide incentives to landowners to make their land more attractive to grassland birds (NRCS 2008), implementation of these programs has not been applied in a spatially targeted manner. Therefore, a concerted effort to delineate priority conservation areas can address this shortcoming and maximize the conservation benefits of these programs.

Many techniques to identify and select areas for the preservation of habitats and species of concern are already available (Knight et al. 2008). The traditional tendency of protecting pristine or scenic areas worked well in times when human population was smaller. Today, the preservation of "healthy" ecosystems in which biodiversity is maintained, even in the presence of humans, requires the integration of well accepted reserve design rules with ecosystem management approaches both at species and ecosystem/landscape levels (Knight & Cowling 2007; Meffe et al. 2002). Several methods are available for the identification of efficient nature reserve networks. Site selection algorithms can be used to select areas that maximize "representation" of species biodiversity, and iterative heuristic algorithms can be used to choose sites that together encompass the largest number of species. However, the use of these computational methods is generally not integrated with management objectives and constraints. To overcome this shortcoming, multicriteria decision analysis (MCDA) has been suggested as a tool to integrate the managers' point of view with the theoretical reserve design techniques (Cabeza & Moilanen 2001).

Multicriteria decision analysis is a procedure that approaches a problem by evaluating a set of alternatives to reach a solution that is meaningful and transparent. The core idea of MCDA methodology is to decompose the problem into manageable components that are analyzed separately and brought together to obtain a logical solution (Malczewsky 1999). MCDA can blend socioeconomic, ecological and institutional context criteria in a systematic way and can involve collaborative decision making thereby increasing the efficacy of conservation planning (Meffe et al. 2002).

Adding the spatial capability of geographic information systems (GIS) to the decision making process offers a practical way to combine geographical data and decision maker's preferences to produce data usable in decision making (Malczewsky 2006). A decision-making process in a spatial multicriteria decision analysis framework can be broken down into several components. First, the problem needs to be defined by the decision maker(s). Criteria, or the basis for a decision that can be measured and evaluated, are then identified. In a spatial framework the criteria are related to geographic entities, thus criteria maps are created. Decision rules are the processes used to combine criteria in order to reach a particular evaluation, and by which evaluations are compared and acted upon (Eastman et al. 1995). The decision rule that we implemented is the Analytic Hierarchy Process. In this method, criteria used to rank grassland parcels were organized hierarchically. Weights were calculated for each criterion of the hierarchy and combined with the correspondent component value using weighted linear sums to obtain the overall score for each parcel (Malczewsky 1999).

Analytic Hierarchy Process (AHP), integrated into a GIS database resulted in quality maps in which patches are classified for their suitability for grassland birds and how prone they are to threats from human interference or activities that degrades them. These maps are provided to managers and stakeholders as a practical tool that can be used to plan a system of protected grassland areas that should conserve or increase grassland bird diversity of the region.

We used the Champlain Valley of Vermont (CV) as a case study. The CV has a relatively large amount of potential habitat (130,000 ha) and is included in the Lower Great Lakes/St. Lawrence plain physiographic Bird Conservation Region, which supports some of the largest populations of grassland birds in eastern North America. These factors have led to the grassland birds being targeted as a conservation priority in the region (Jones et al. 2000; Rich et al. 2004). Despite the large acreage of potential habitat in the CV, much of this land is privately owned and managed for a variety of purposes (especially dairy farming) that may be at odds with conservation of grassland bird populations (Troy et al. 2005). The identification and conservation of high quality habitat for grassland birds and the implementation of bird-friendly management should guarantee not only maintenance of an agricultural landscape, vital to and characteristic of Vermont, but more importantly enhance grassland bird biodiversity.

Methods

Study area

The Champlain Valley is a 600,000 ha region in the northeastern portion of North America that surrounds Lake Champlain and is divided between the states of Vermont and New York and the Canadian province of Quebec. We studied the Vermont portion of the Champlain Valley (CV), considered as the territory included in Franklin, Grand Isle, Chittenden and Addison counties. The land use/land cover of the CV is 26% agriculture, 50% forest, 9% urban, 13% lakes and rivers and 2% wetlands (O'Neil-Dunne 2001). In Vermont, agricultural land use includes almost 130,000 ha (over 32,500 grassland patches). The grassland patches are distinguished as crop fields, including corn, hay, other crops, and fallow, or suburban pastures, including either agriculture pastures or large non-agricultural (suburban) fields. These grassland patches are identified as the smallest units of land characterized by the same land cover, land management, and owner, and bounded by permanent features such as roads, water bodies, fence lines, and hedgerows (USDA 2008).

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process is a widely used structured technique to address spatial multi-attribute decision making processes. AHP is easily incorporated into GIS-based analysis, can be used by one or more decision makers, and identifies and accounts for inconsistencies of decision makers. In this method, the decision maker(s) breaks down the decision problem in a hierarchical format that, starting from the goal (level one; identifying priority conservation areas for grassland birds; Fig. 1), moves step by step through the hierarchy, defining criteria, standardizing values, assigning weights and producing rating maps. Landscape and patch components represent the second level of the hierarchy and the criteria within each of these components represent the third level of the hierarchy.

The quality value for the patch, summarized in the rating maps, was obtained using an additive model, by summing the result of the multiplication of weights by criteria within each component ($Component\ value = \sum w_i x_i$ where x_i is the score for each parcel for the ith criterion and w_i is the weight for the same criterion [$\sum w_i = 1$ and $0 \leq w_i \leq 1$]), and then summing the result of the multiplication of weights by components ($patch\ value = \sum w_j Land + \sum w_j Patch$ where w_i is the weight for each component and Land and Patch are the component values [$\sum w_j = 1$ and $0 \leq w_j \leq 1$]) (Malczewsky 1999). We repeated this process across 36 scenarios (see sensitivity analysis section below for more details), generated by changing weights both at component level (landscape or patch) and criteria level (grassland, development, forest and road within landscape: patch size, perimeter/area, management and conservation status within patch). For the expert scenarios, criteria on the same level of the hierarchy were compared with each other on a pairwise basis to decide criterion weights (on the basis of expert opinion), and then weights were multiplied by the criteria map values. For all the other scenarios, the weights were determined by interpreting the literature. To determine if the comparisons used to calculate the weights were consistent, a consistency ratio (CR) was calculated (Malczewsky 1999; Saaty 1980).

Criteria

Both patch- and landscape-level characteristics were included in the criteria definition in AHP. Patch-level characteristics such as area, shape, and isolation are known to affect wildlife populations. However, landscape-level characteristics, the configuration and composition of the landscape mosaic, have recently been shown to have equally important effects on the viability of animal populations (Bakker et al. 2002; Ribic & Sample 2001; Rodewald 2003). In addition, we included as patch level characteristics two criteria: conservation status of the grassland patch or its use type (intensively farmed or leisurely managed). These criteria cannot be used by birds as a settlement cue but address threats from human interference such as early hay cuts, frequent hay cuts, intensive grazing, etc and were included to direct the selection toward grassland patches that are not intensively used for agriculture (i.e., suburban grasslands and pastures) and already conserved areas where the application of bird-friendly management may be more feasible.

The identification of priority conservation areas for grassland birds was organized hierarchically, and the criteria were used to reach the decision goal of ranking the grassland patches on the basis of their quality for grassland birds. To do so, weights were calculated for each criterion within the hierarchy and combined with the correspondent component value to obtain the overall score for each parcel (Malczewsky 1999).

We first conducted an extensive literature review and contacted local experts on grassland bird species to determine which criteria were important in grassland bird habitat selection and needed to be included in the analysis. Seven criteria were included in the classification on the basis of the literature review and expert opinion. The landscape attributes, or criteria, were grouped into the landscape component. The patch criteria, including human perceived characteristics, were grouped into the patch component.

The landscape component criteria that we used were forest, grassland and developed habitat area in a 3000 m buffer around each patch; and distance of each patch from major roads. Bakker et al. (2002) and Rodewald (2003) found roads, forests, agriculture, and urban development to be the main land uses within a landscape that affect richness, abundance, occurrence and density of grassland birds in the landscape matrix. Thus, we used forest, grassland and development to generate maps in which grassland patches were scaled, using values between 0 and 1, on the basis of the amount of forest, grassland or developed habitat that was present within a 3000 m buffer around each patch. Traffic, and in particular traffic noise, can also affect avian communities within several hundred meters of roads (Forman et al. 2002; Reijnen et al. 1996). Because grassland birds tend to avoid suitable habitat close to roads (Forman et al. 2002; Reijnen et al. 1996), we categorized the grassland patches using their distance from roads attributing a value of 1 to patches farther than 700/1200 m from different categories of highly trafficked roads, a value of 0 to patches included within the 1200 m buffer and values between 0 and 1 for patches in between these distances.

Three criteria were included in the patch component: size of each grassland patch, management type (agricultural or recreational), and conservation. The area criterion addresses the tendency of grassland birds to favor large grassland patches and avoid or use less frequently small patches of favorable habitat (Herkert 1994; Vickery et al. 1994; Walk & Warner 1999). However, two patches of similar-sized grasslands may have different abilities to support grassland birds because of differences in patch shape and, as a result, edge effects. Some of the negative effects of edges on grassland birds are higher predation and parasitism rates on nests close to forested edges and edge avoidance by some grassland birds (Helzer & Jelinski 1999). Perimeter-area ratio can be use to characterize the amount of patch area exposed to edges without any subjective analysis on the distance affected by the edge effect. For the sensitivity analysis and in the calculation of priority indices area and ratio perimeter/area criteria are used alternatively because of their strong correlation.

Generally, management activities on grassland fields have a negative impact on grassland birds. When hayfields are mowed during the breeding season, the reproductive success of grassland birds is reduced (Bollinger et al. 1990). But, if haying is delayed until late summer when the breeding season is over, mowing can be seen as a way to set back succession and maintain suitable habitat (Warren & Anderson 2005). In addition to the benefit of a "lighter" hayfield management, in New England and in the CV there are many landowners who own large portions of grasslands formerly managed as hayfields but are now lightly managed and still available to grassland birds. These non-agricultural landowners seem to have fewer economic constraints and might be more inclined to adopt bird friendly managements practices (Troy et al. 2005).

Because crop rotation is a common practice in the CV, it is difficult to generate a static GIS layer that includes current information on the management of each grassland patch. However, the spatial data used in this analysis were separated into two separate layers. The first included fields used for agricultural purposes that may be in corn production during some years and may be idle or rotated to grass or legume forage crops in other years, when they would be available to grassland birds. The second included patches of grassland that are currently managed as pasture or suburban grassland habitats. Taking advantage of this classification, we considered it to be valuable to prioritize patches in the second layer in the management criteria.

Parks, nature preserves and land easements that include grassland can be used as core areas for reserves and can complement patches outside of protected areas that might be too small to be considered for protection on their own. Further, owners that are already aware of the importance of preserving natural resources might be more likely to apply grassland bird-friendly managements to their already protected land. Pre-existing protected areas were introduced in the model using a layer produced by the Spatial Analysis Laboratory at the University of Vermont. This feature class included public and private parcels that are under any kind of land and natural resources conservation program. The conserved layer was interpolated with the grassland patch distribution to obtain a ranked value of the grassland patches on the basis of their inclusion in already protected areas. Grassland patches in the conserved criterion were scored (values vary between 0 and 1) based on the proportion of their area included in a preserved area.

We used ArcGis to generate quantitative scores for each criterion. Grassland patches received a score for each criteria and these values were standardized using a linear scalar transformation so that different numerical scales could be compared on a scale from 0 to 1 (Malczewsky 1999). Management, conserved and road criteria were already on a scale that varied between 0 and 1 and did not need to be normalized.

To determine the relative importance of each criterion and to designate the weights to give to the criteria, first we looked at the literature and then prepared a survey that was administered to seven grassland bird experts. We structured the survey in a way in which each criterion was compared with the others within the same component using the pairwise comparison method (Saaty 1980).

Sensitivity analysis

We conducted a sensitivity analysis to address the effects of variation in the model parameters due to the lack of precise knowledge of the relative importance of each criterion for grassland bird habitat selection. The 36 potentially equally valid set of scenarios that we developed were the result of variation in the weights assigned to component-level and criteria-level variables regarding their relative importance for grassland birds. At the component level, we evaluated the relative importance of the sum of landscape variables versus the sum of patch variables. Weights for landscape and patch variables varied (tables 1 to 3) to allow analysis of a wide spectrum of possible outcomes (Lowry et al. 1995). Because both patch and landscape components are recognized in the literature as factors used in breeding habitat selection by grassland birds, and because the inclusion of human-based criteria are needed to facilitate the conversion of the model result into on-the-ground conservation actions, we did not include strategies that accounted for only one of the components.

Outcome from the sensitivity analysis was used to rank each grassland patch and for the selection of priority conservation areas. Within each scenario map, grassland patches were classified into 5 quality classes. Because the resulting values from each scenario varied between 0 and 1, the 5 quality classes were identified as follows: “Very low” (values

$0 \leq x < 0.2$), “Low” (values $0.2 \leq x < 0.4$), “Medium” (values $0.4 \leq x < 0.6$), “High” (values $0.6 \leq x < 0.8$), and “Very high” (values $0.8 \leq x \leq 1$). Patches were deemed to be high priority for grassland bird conservation based on their frequency of occurrence in the high and very high quality categories across all scenarios. Patches that scored high in many of the 36 scenarios (regardless of the weights attributed to criteria and components) were considered “robust.”

Priority conservation areas identification

Once the grassland patches in the CV were ranked on the basis of their quality for grassland birds, managers will have to select the priority areas for outreach, conservation, and management. There are several methods that can be used to select which patches should be prioritized especially when considering the many constraints that managers must address. Willingness of owners to be involved in some kind of management, pecuniary availability for purchase of particularly important areas, connectivity concerns, etc. may influence the decision of areas on which to focus their attention. In this paper we present four examples obtained using simple Boolean operations in ArcGIS. We selected areas of good quality larger than 100/200 ha to assure the potential for grassland bird breeding events.

Results

Sensitivity and assumptions analysis

We generated a scatter plot matrix to compare scenarios in a pairwise fashion and verified the congruence of ranking for each grassland patch. Over the 630 scenario comparisons, intermediate priority patches showed a greater tendency for less congruence in ranking. Higher and lower priority grassland patches were generally characterized by superior and inferior condition for all criteria respectively and were less sensitive to changes in weights. Intermediate priority grassland patches are more subjected to the changes due to weights because were characterized by criteria values that vary for each criterion and are not as extreme as for the cells identified as of higher or lower priority (Geneletti & Van Duren 2008).

The perimeter/area ratio as opposed to patch area criterion tended to shift the patch quality toward higher values. Furthermore, the management criteria-level scenario seemed to be influential in driving patch values toward higher levels. All grassland patches that were part of the suburban pasture layer received a value for the criterion management of 1. This high criterion value combined with its high weight in the management patch scenario probably led to the high quality values in these scenarios (figure 3).

Quality map

Our model prioritized 7,538 grassland patches with habitat characteristics suitable for grassland birds and with higher potential to be enrolled in bird-friendly management, totaling an area of approximately 33,600 ha. The grassland patches identified in the quality map (Fig. 2) were then compiled using geo-political boundaries (counties, towns, conservation districts), and ecological boundaries (watersheds, physiographic units). At the county and town levels, analyzed per request of local managers, the map identified large portions of Franklin and Addison counties as areas with the highest ranking and largest tracts of contiguous good quality grassland patches. The towns that on average included higher quality grasslands and where efforts should be concentrated are: all of the towns along Lake Champlain in Addison county; Charlotte, Shelburne and Hinesburg in Chittenden county; and St. Albans Town, Highgate, and Sheldon in Franklin county. In Grand Isle county, the partial isolation of some of the grassland patches and domination of the landscape by Lake Champlain caused grassland patches to score lower than other CV counties, but priority patches were also present in this county.

The quality map is not only a ranking of all grassland patches in the CV to be used to prioritize the promotion of agri-environmental incentive programs. Indeed, it will also be used to identify the largest and highest ranking grassland fields located in between the already conserved blocks to improve connectivity. Conserved areas that are protected by the Vermont Land Trust and the Vermont Fish and Wildlife Department are classified as priority grassland patches and should be considered as starting points for outreach programs to promote bird-friendly managements.

Priority conservation areas identification

To identify priority conservation areas for grassland birds, we selected blocks of patches of grassland using Boolean expressions (Fig. 3). We applied threshold values, and we categorized blocks on the basis of minimum area requirement. To support a higher grassland bird diversity, grassland patches needed to be larger than 50 ha, even if smaller patches (5-10 ha) can be beneficial breeding sites for more common songbirds (Vickery et al. 1994). Following these suggestions but considering uncertainties and visual simplicity, we aggregated priority patches. First, we aggregated abutting or as close as 10 m patches of high quality where the cumulative area was ≥ 100 ha, large enough to support breeding events of most grassland passerines. The non adjacent patches were separated by boundaries that did not interfere with grassland bird movements, such as small dirt roads, narrow and low hedgerows, ditches or drainages. Second, we aggregated high priority patches where the cumulative area was ≥ 200 ha, large enough to support breeding events of larger grassland birds such as Upland Sandpiper (*Bartramia longicauda*). Finally, we aggregated high and intermediate priority patches to produce even larger blocks of contiguous grasslands.

Discussion

The combination of GIS and multicriteria decision analysis and the use of AHP offered a compromise in incorporating theoretical reserve design techniques and management requirements. Furthermore, this approach integrated both landscape and patches level factors and has the potential of analyzing together species and habitat data. Although our methodology was specifically applied to grassland bird habitat in the CV, it can be a practical tool for conservation prioritization of different species and in different locations.

The multicriteria process has the advantage of being easily updated and repeatable as new data become available. The quality maps were created using 7 criteria that incorporate both attributes of the site as perceived by grassland birds, and human-based characteristics.

These criteria offered the advantages of being easy to obtain or generate, applicable at the chosen spatial scale, and easily modified to extract the desired data. For the sake of practicality and simplicity of the model, the chosen criteria were not exhaustive in covering all characteristics that are known to correlate with grassland bird habitat selection and human influence. However, additional factors could be easily incorporated into the analysis. For example, information on soil, vegetation, inter- and intra-specific interactions, current management regimes, and socio-economic factors connected with agricultural activities are factors that may influence the habitat selection decisions of grassland birds. While our analysis was not comprehensive, it provides a streamlined starting point for management planning that is more likely to be applicable than one that include too many criteria (Malczewsky 1999).

New and/or more precise criteria maps can be generated with the availability of new spatial data, repeating the multicriteria analysis with the inclusion of the additional data. Different weights could also be attributed to the criteria if new relationships between grassland habitat selection processes are discovered or if new criteria are included into the process. At the same time, if the process described above will be used for the prioritization of conservation areas for different species or in sites different than the CV, a different set of criteria can be identified and implemented. The division into components should also be revised to group adequately the criteria chosen. For example, criteria values for cost of patches acquisition, level of involvement of each patch owner, and stakeholder perceived value for each patch, once available, could all be included in a new socio-economic component to add to the analysis.

The involvement of experts in the decision-making process selection of the procedure scheme, and criteria choice for the methodology can improve the quality of the final results. We contacted, using a survey, 7 grassland bird experts for the weight's definition. In the survey, the experts were asked to compare pairs of criteria and decide which of the two was more important, and quantify the intensity of importance with respect to habitat selection for grassland birds using the Saaty (1980) scale. The same methodology could be used as new criteria become available, even enlarging the panel of experts or opening it to stakeholders, to offer further knowledge and perspectives in the decision process (Geneletti 2007).

The study presented here constitutes a step forward in the production of a more accurate habitat quality classification of the CV for grassland birds. Utilizing a vector-based spatial dataset, combined with information on the management of grassland parcels provides a more precise delineation of the grassland patches with relatively up-to-date information on management practices. Such precision cannot be obtained using a raster-based approach. The advantages of using parcel-based maps include: ease of tracking patch shape changes and simplicity of joining additional information to the spatial dataset that could be used for statistical analysis.

Recent datasets were also used in the generation of criteria maps, assuring up-to-date results. However, any maps produced with a methodology similar to this one for habitats that are subject to periodic changes in use and cover are time sensitive and should be considered a snapshot of a land use changes vary continually (Puryear 2004).

In many reserve design scenarios (Carrion et al. 2008; Malczewsky 1999; Sener 2004) constraints were used to exclude unsuitable habitat from the analysis. In our procedure the only constraint utilized was the extent of suitable habitat for grassland birds: only grassland habitats were considered. The constraint that identified the suitable habitat was applied before the start of the analysis such that non-grassland habitats were excluded from the analysis and quality values were not calculated for these patches. Cost criteria, included in our process were standardized using a “reverse” formula that gave lesser values to the patches that have greater costs for the criterion analyzed. Patches with standardized values of zero for certain criteria were not automatically excluded as unsuitable patches, but a zero value contributed to lowering the overall quality score of the patch.

Reserve maps produced using Boolean selection provided a good representation of the use of quality maps for the delineation of a reserve system. Acknowledging that the size of a reserve is correlated to the number of species that it can support (Diamond 1975), and the fact that most grassland species are area sensitive and some, in particular Upland Sandpiper, require very large continuous grasslands (Houston & Bowen 2001), the selection process was based on threshold sizes of 100 and 200 ha as suggested by Vickery et al. (1994). Some of the maps generated using the quality map as starting point provide a well laid out reserve system with reserves distributed especially in Addison county where most of the grassland patches are distributed. If a metapopulation model is assumed for these populations, the spatial distribution of blocks should allow the exchange of individuals between patches. Reserve maps could also be produced for scenarios in which, for instance, number of species protected, potential nest sites available, number of individual produced per year, costs of patch acquisition are calculated.

Studies to better understand the factors that influence habitat selection strategies for grassland birds should be pursued. Given the uncertainty about mechanism(s), relative importance of patch and landscape criteria, vegetation, criteria-level habitat, prey and predator abundance, climate etc. in explaining habitat selection and species richness, new research projects (Hamer et al. 2006) on this matter will help refine the choice of high priority conservation areas for grassland birds.

The quality maps should be considered as the "foundation" on which the preservation of grassland birds for the CV can be built. Managers and stakeholders now have a new tool that can help guide outreach for alternative management practices and conservation promotion where they should have the greatest chance of success in conserving grassland birds. The methods used to generate the quality maps and the tools created in ArcGIS can be thought of as "blue prints" that can be copied as is or modified for specific needs in identifying priority conservation areas. The versatility of MCDA, AHP and the spatial capability of the methodology applied in the CV to identify priority conservation areas for grassland birds can be easily modified to address specific needs for different locations. Other species, guilds, taxa, and/or communities could be the beneficiary of a new plan that implements our methodology. Even more, abundance, presence, or richness data for the species or group of interest could be included in the criteria set together with habitat and socioeconomic data. Also, management information could find a place in this hypothetical criterion set. Stakeholders, politicians and experts can all be involved in the decision process at different levels, and quality maps, resulting from the multicriteria decision analysis, can be used for reserve designing and ecosystem management planning.

Literature Cited

Askins, R. A. 1999. History of grassland birds in Eastern North America. Studies in Avian Biology **19**:60-71.

Bakker, K. K., D. E. Naugle, and K. F. Higgins. 2002. Incorporating landscape attributes into models for migratory grassland bird conservation. Conservation Biology **16**:1638-1646.

Bollinger, E. K., P. B. Bollinger, and T. A. Gavin. 1990. Effects of hay-cropping on Eastern populations of the Bobolink. Wildlife Society Bulletin **18**:142-150.

Cabeza, M., and A. Moilanen. 2001. Design of reserve networks and the persistence of biodiversity. TRENDS in Ecology & Evolution **16**:242 - 248.

Cameron, S. E., K. J. WIlliams, and D. K. Mitchell. 2008. Efficiency and concordance of alternative methods for minimizing opportunity costs in conservation planning. Conservation Biology **22**:886-896.

Carrion, A. J., E. A. Estrelle, A. F. Dols, Z. M. Toro, R. M., and R. R. A. 2008. Environmental decision-support system for evaluating the carrying capacity of land areas: Optimal site selection for grid-connected photovoltaic power plats. Renewable and Sustainable Energy Reviews **12**:2358-2380.

Cunningham, M. A. 2005. A comparison of public lands and farmlands for grassland bird conservation. The Professional Geographer **57**:51-65.

Cunningham, M. A., and D. H. Johnson. 2006. Proximate and landscape factors influence grassland bird distribution. Ecological Applications **16**:1062-1075.

Diamond, J. M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biological Conservation **7**:129-146.

Eastman, R. J., J. Weigen, K. P. A. K., and J. Toledano. 1995. Raster procedures for multi-criteria/multi-objective decisions. Photogrammetric Engineering & Remote Sensing **61**:539-547.

Forman, R. T. T., B. Reineking, and A. M. Hersperger. 2002. Road Traffic and Nearby Grassland Bird Patterns in a Suburbanizing Landscape. Environmental Management **29**:782-800.

Geneletti, D. 2007. An approach based on spatial multicriteria analysis to map the nature conservation value of agricultural land. Journal of Environmental Management **83**:228-235.

Geneletti, D., and I. Van Duren. 2008. Protected area zoning for conservation and use: A combination of spatial multicriteria and multiobjective evaluation. Landscape and Urban Planning **85**:97 - 110.

Hamer, T. L., C. H. Flather, and B. R. Noon. 2006. Factors associated with grassland bird species richness: the relative roles of grassland area, landscape structure and prey. Landscape Ecology **21**:569 - 583.

Helzer, C. J., and D. E. Jelinski. 1999. The relative importance of patch area and perimeter-area ratio to grassland breeding birds. Ecological Applications **9**:1448-1458.

Herkert, J. R. 1994. The effects of habitat fragmentation on the midwestern grassland bird communities. Ecological Applications **4**:461-471.

Houston, C. S., and D. E. J. Bowen. 2001. Upland Sandpiper (Bartramia longicauda), The Birds of North America Online. Cornell Lab of Ornithology, Ithaca. Available from http://bna.birds.cornell.edu.bnaproxy.birds.cornell.edu/bna/species/580 (05/25, 2009)

Jones, A. L., W. G. Shriver, and P. D. Vickery. 2000. Regional inventory of grassland birds in New England and New York, 1997 - 2000 in C. f. b. conservation, editor. Massachusetts Audubon Society, Lincoln, MA.

Knight, A. T., and R. M. Cowling. 2007. Embracing Opportunism in the Selection of Priority Conservation Areas. Conservation Biology **21**:1124 - 1126.

Knight, A. T., R. M. Cowling, M. Rouget, A. Balmford, A. T. Lombard, and B. M. Campbell. 2008. Knowing But Not Doing: Selecting Priority Conservation Areas and the Research–Implementation Gap. Conservation Biology **22**:610-617.

Lowry, J. H., H. J. Miller, and G. F. Hepner. 1995. A GIS-based sensitivity analysis of community vulnerability to hazardous contaminants on the Mexico/U.S. border. Photogrammetric Engineering & Remote Sensing **61**:1347-1359.

Malczewsky, J. 1999. Gis and multicriteria decision analysis. John Wiley & Sons, INC.

Malczewsky, J. 2006. GIS-based multicriteria analysis: a survey of the literature. International Journal of Geographical Information Science **20**:703-726.

Meffe, G. K., L. A. Nielsen, R. L. Knight, and D. A. Schenborn 2002. Ecosystem Management: adaptive, community-based conservation. Island Press.

Norment, C. 2002. On grassland bird conservation in the Northeast. The Auk **119**:271-279.

NRCS. 2008. Conservation programs - Vermont NRCS. NRCS. Available from http://www.vt.nrcs.usda.gov/programs/ (February 23, 2009)

O'Neil-Dunne, J. 2001. Updated Land Use / Land Cover and Phosphorous Loading for the Lake Champlain Basin. Burlington. Available from http://www.vcgi.org/dataware/ (02, February 2009)

Perlut, N. G., A. M. Strong, T. M. Donovan, and N. J. Buckley. 2006. Grassland songbirds in a dynamic management landscape: behavioral responses and management strategies. Ecological Applications **16**:2235-2247.

Perlut, N. G., A. M. Strong, T. M. Donovan, and N. J. Buckley. 2008. Regional population viability of grassland songbirds: Effects of agricultural management. Biological Conservation **141**:3139-3151.

Puryear, K. 2004. Landscape-level grassland bird conservation in the southern Champlain valley, Vermont. Page 159. The University of Vermont, Burlington.

Reijnen, R., R. Foppen, and H. Meeuwsen. 1996. The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. Biological Conservation **75**:255-260.

Ribic, C. A., and D. E. Sample. 2001. Associations of grassland birds with landscape factors in southern Wisconsin. The American Midland Naturalist **146**:105-121.

Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. W. Demarest, E. H. Dunn, W. C. Hunter, E. E. Iñigo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendt, and T. C. Will. 2004. Partners in Flight North American Landbird Conservation Plan. in C. L. o. Ornithology, editor. Cornell Lab of Ornithology, Ithaca, NY.

Rodewald, A. D. 2003. The importance of land uses within the landscape matrix. Wildlife Society Bulletin **31**:586-592.

Saaty, T. L. 1980. The Analytic Hierarchy Process. McGraw-Hill, Inc.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966 - 2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel. Available from http://www.mbr-pwrc.usgs.gov/bbs/bbs.html (Jan 15, 2009)

Schlaepfer, M. A., R. M. C., and S. P. W. 2002. Ecological and evolutionary traps. Trends in Ecology & Evolution **17**:474 - 480.

Sener, B. 2004. Landfill site selection by using Geographic Information Systems. Page 114. Department of Geological Engineering. Middle East Technical University, Ankara.

Troy, A. R., A. M. Strong, S. C. Bosworth, T. M. Donovan, N. J. Buckley, and M. L. WIlson. 2005. Attitudes of Vermont dairy farmers regarding adoption of management practices for grassland songbirds. Wildlife Society Bulletin **33**:528-538.

USDA. 2008. Common Land Unit (CLU). Available from http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prod&topic=clu (February 10, 2009)

Vickery, P. D., M. L. Hunter JR, and S. M. Melvin. 1994. Effects of habitat area on the distribution of grassland birds in Maine. Conservation Biology **8**:1087-1097.

Walk, J. W., and R. E. Warner. 1999. Effects of habitat area on the occurrence of grassland birds in Illinois. The American Midland Naturalist **141**:339-344.

Warren, K. A., and J. T. Anderson. 2005. Grassland songbird nest-site selection and response to mowing in West Virginia. Wildlife Society Bulletin **33**:285-292.

Flavio Sutti and Allan Strong – Identifying priority conservation areas for grassland birds

Figures Legends

Figure 1: Analytic hierarchy process for creating quality maps to prioritize grassland patches in the Champlain Valley (modified from Malczewski 1999).

Figure 2: Effect of the Ratio perimeter/area and Management analyzed by averaging scenarios' priority values. Averages of scenarios where the "Ratio" is used in the criteria-level strategies and where both "Management" and "Ratio" criteria-level strategies are used are significantly higher (overall ANOVA $F = 22.29$, $p < 0.0001$, Tukey-Kramer $p < 0.05$) than management only or expert strategies.

Figure 3: Quality map classified with 3 patch categories. Each grassland patch is categorized as either poor (scored in the high or very high categories < 9 times across all 36 scenarios), intermediate (9-17 high or very high scores) or good (> than 18 high or very high scores).

Figure 2: Four examples of priority conservation areas for grassland birds obtained from the quality map.

Figure 1:

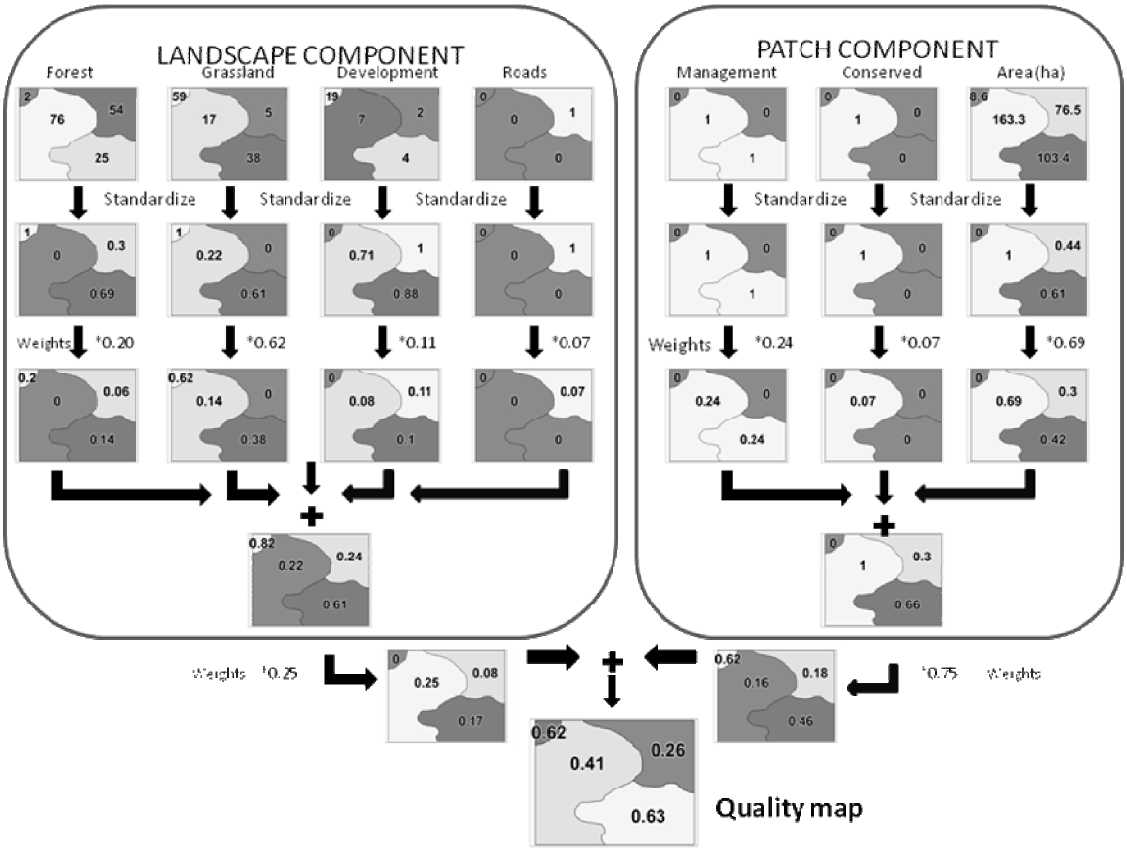

Figure 2:

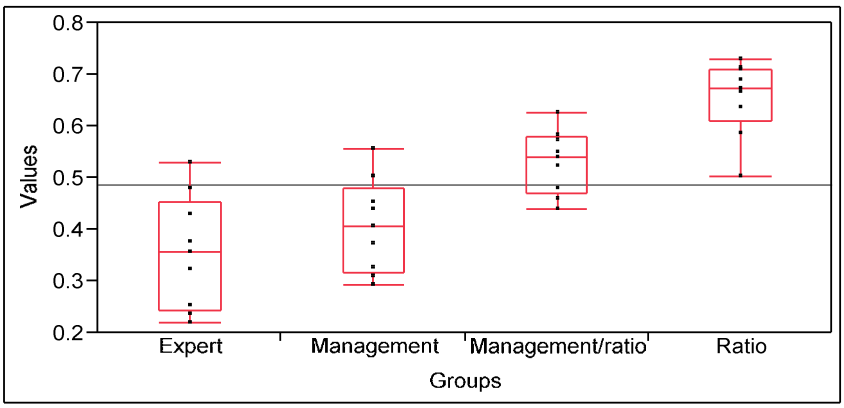

Figure 3:

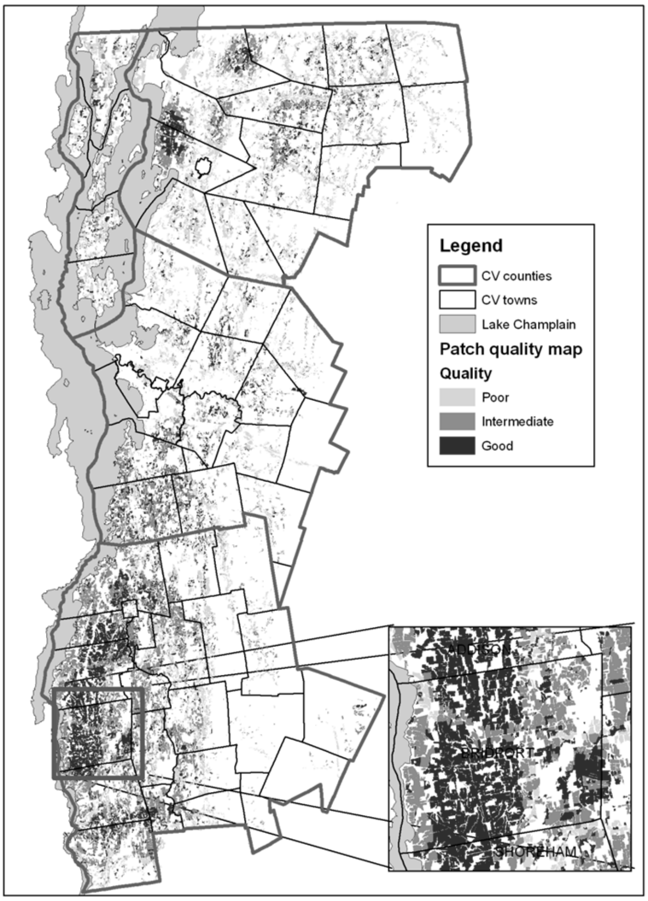
Legend
CV counties
CV towns
Lake Champlain
Patch quality map
Quality
Poor
Intermediate
Good
ADDISON
BRIDPORT
SHOREHAM

Figure 4:

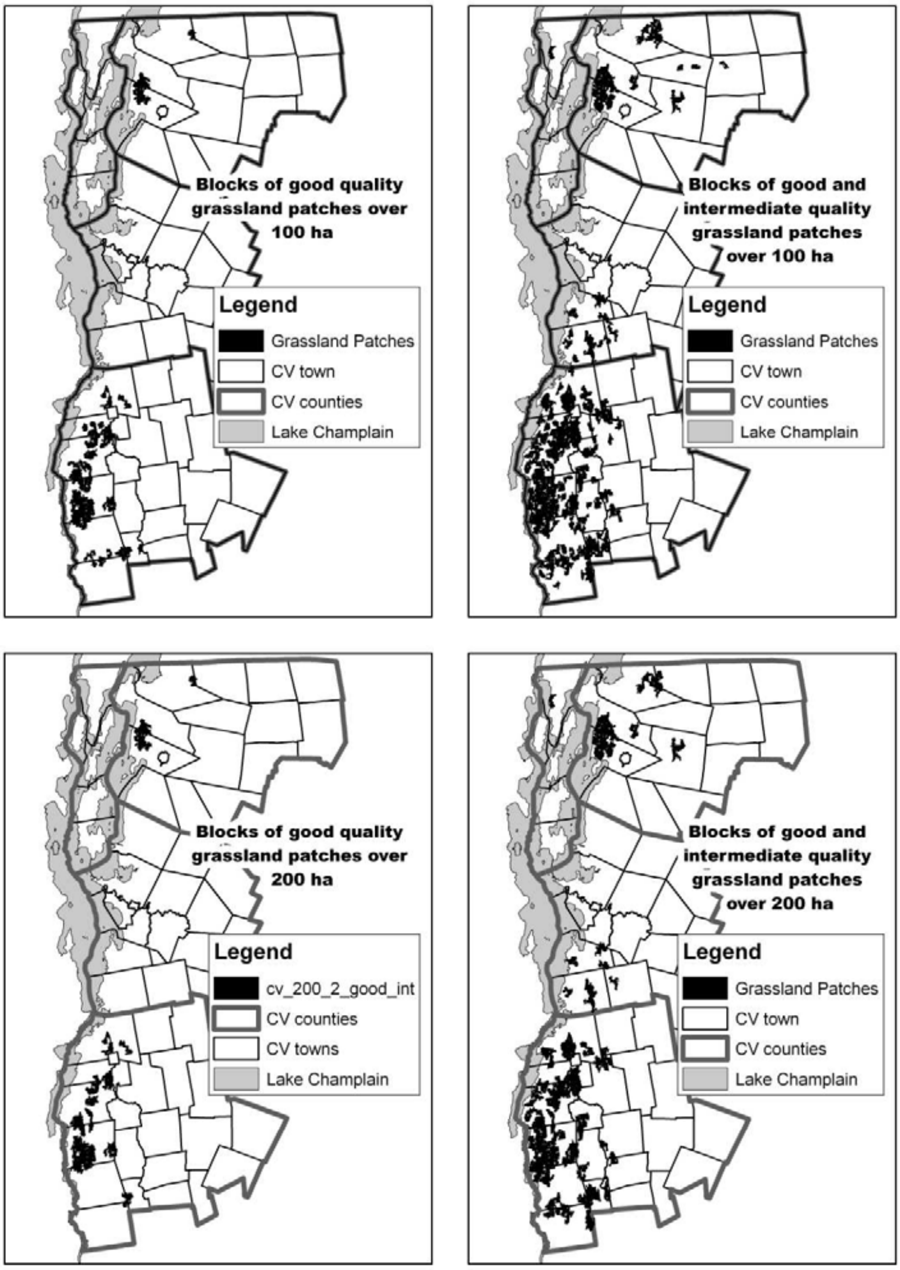
Blocks of good quality grassland patches over 100 ha
Legend
Grassland Patches
CV town
CV counties
Lake Champlain
Blocks of good and intermediate quality grassland patches over 100 ha
Legend
Grassland Patches
CV town
CV counties
Lake Champlain
Blocks of good quality grassland patches over 200 ha
Legend
cv_200_2_good_int
CV counties
CV towns
Lake Champlain
Blocks of good and intermediate quality grassland patches over 200 ha
Legend
Grassland Patches
CV town
CV counties
Lake Champlain

Table 1: Summary of the component-level strategies including description and weight attributed.

	Description	Weighting coefficient	
Component strategy M1	Landscape component equal to Patch component	Landscape:	0.5
		Patch:	0.5
		Sum:	1
Component strategy M2	Landscape component more important than Patch component	Landscape:	0.75
		Patch:	0.25
		Sum:	1
Component strategy M3	Patch component more important than Landscape component	Landscape:	0.25
		Patch:	0.75
		Sum:	1

Table 2: Summary of the criteria-level strategies within the LANDSCAPE component, including description and weight attributed.

	Description	Weighting coefficient	
Criteria Strategy LAND1 - EQUAL	All criteria proportionally equal	Grassland	0.25
		Forest	0.25
		Development	0.25
		Roads	0.25
		Sum	1
Criteria Strategy LAND2 – OPEN	Openness of the landscape is prioritized (based on Shustack 2004)	Grassland	0.48
		Forest	0.11
		Development	0.11
		Roads	0.3
		Sum	1
Criteria Strategy LAND3 - EXPERT	Expert opinion that prioritizes grasslands over other criteria	Grassland	0.62
		Forest	0.2
		Development	0.11
		Roads	0.07
		Sum	1

Table 3: Summary of the Ccriteria-level strategies within the PATCH component, including description and weight attributed.

	Description	Weighting coefficient	
Criteria Strategy PATCH1 - MANAGEMENT	Management criteria is prioritized	Area	0.31
		Management	0.58
		Conserved	0.11
		Sum	1
Criteria Strategy PATCH2 - EXPERT2	Expert opinion that prioritizes area over all other criteria	Area	0.69
		Management	0.24
		Conserved	0.07
		Sum	1
Criteria Strategy PATCH3 - MANAGEMENT_PA	Management is prioritized and perimeter/area ratio is used instead of area criteria	Perimeter/area	0.31
		Management	0.58
		Conserved	0.11
		Sum	1
Criteria Strategy PATCH4 - EXPERT2_PA	Expert opinion that prioritizes area over all other criteria (perimeter/area ratio used instead of area)	Perimeter/area	0.69
		Management	0.24
		Conserved	0.07
		Sum	1