A Case Study of Assigning Conservation Value to Dispersed Habitat Units for Conservation Planning

Jason J. Rohweder*; Sara C. Vacek; Shawn M. Crimmins; Wayne E. Thogmartin

Resource managers are increasingly tasked with developing habitat conservation plans in the face of numerous, sometimes competing, objectives. These plans must often be implemented across dispersed habitat conservation units that may contribute unequally to overall conservation objectives. Using U.S. Fish and Wildlife Service waterfowl production areas (WPA) in western Minnesota as our conservation landscape, we develop a landscape-scale approach for evaluating the conservation value of dispersed habitat conservation units with multiple conservation priorities. We evaluated conservation value based on a suite of variables directly applicable to conservation management practices, thus providing a direct link between conservation actions and outcomes. We developed spatial models specific to each of these conservation objectives and also developed two freely available prioritization tools to implement these analyses. We found that some WPAs provided high conservation value across a range of conservation objectives, suggesting that managing these specific areas would achieve multiple conservation goals. Conversely, other WPAs provided low conservation value for some objectives, suggesting they would be most effectively managed for a distinct set of specific conservation goals. Approaches such as ours provide a direct means of assessing the conservation value of dispersed habitat conservation units and could be useful in the development of habitat management plans, particularly when faced with multiple conservation objectives.

Keywords: Conservation, Minnesota, prioritization, spatial overlay, conservation planning tools, Wetland Management Districts, Waterfowl Production Areas

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INTRODUCTION

Conservation agencies are increasingly tasked with developing habitat and conservation management plans in the face of numerous, and sometimes competing, conservation objectives despite financial and staffing limitations. In many cases, managers could benefit from conservation planning tools that provide transparent, objective, and rapid evaluations of the potential outcomes resulting from various conservation or management actions (Johnson et al. 2010). This need led to the development and evaluation of numerous approaches for prioritizing conservation actions and planning strategies (Crous et al. 2013, Hoekstra 2012, Wilhere et al. 2008, Thogmartin et al. 2011), with a growing emphasis on science-based approaches (e.g., Newbold and Siikamaki 2009). Because of the limited resources available to management agencies, much of this effort has focused on optimizing management actions to achieve the greatest conservation outcomes (Beaudry et al. 2011, Carroll et al. 2010, Whitney et al. 2012). These efforts have led to a widespread acceptance of the idea that assessments of conservation actions should be framed explicitly in the context of conservation management decisions in order to convey the greatest value (Sewall et al. 2011). Thus, maximizing conservation value is critical for developing sound management frameworks.

Despite many efforts to develop conservation prioritization strategies, two key issues are often neglected when developing conservation planning tools. The first is how to plan management when trying to achieve multiple objectives. Most conservation planning tools are based on a single conservation objective, such as conserving habitat for a single species or species group of interest (e.g., Bonnot et al. 2013). Comparatively few efforts have been made to develop conservation planning tools that can account for multiple, sometimes competing, conservation objectives. The second issue is how to effectively account for dispersed habitat conservation units. Most conservation managers are familiar with the “SLoSS” (single large or several small) debate regarding reserve design (e.g., Diamond 1975), whereby larger habitat areas are preferred over numerous smaller areas for conserving biodiversity. Unfortunately, the abundance of theoretical and empirical work that has gone into this debate provides little guidance for natural resource managers tasked with managing existing networks of protected areas, which are often dispersed throughout a fragmented landscape. Individual management units vary in size, habitat composition, and landscape context; not every unit will meet conservation objectives equally. Developing conservation strategies can be particularly challenging when dealing with fragmented habitats or dispersed conservation units due to issues of connectivity (Berger et al. 2010, Rudnick et al. 2012). Thus, a pressing need exists for developing conservation planning tools designed to account for the dispersed and fragmented nature of extant habitat conservation networks.

There is increasing recognition of the importance of spatial information for conservation planning in marine (Costello et al. 2010) and terrestrial (Faleiro et al. 2013) systems, and for an emphasis on prioritization approaches in general (Thogmartin et al. 2011, Game et al. 2013). This is particularly critical when prioritizing conservation actions across dispersed habitat units, where spatial context can be important to evaluating the effectiveness of conservation actions. Our objective was to develop, through close collaboration with conservation managers and other relevant stakeholders, spatial models and associated conservation planning tools for prioritizing management on dispersed conservation units. The tools would objectively rank each unit’s conservation value (i.e., potential to achieve habitat objectives), giving managers a transparent way to prioritize management at sites that would meet multiple objectives and to design site-specific management plans based on the most appropriate conservation objectives. We developed our conservation planning tools for a U.S. Fish and Wildlife Service wetland management district (WMD) that has numerous management objectives and is comprised of many spatially dispersed habitat units. Because the tools needed to be easy to use, they were developed with Microsoft Access and include an easy-to-use graphical user interface. The tools allow the user to interactively modify individual input parameter weightings and calculate new objective and overall model result scores on-the-fly.

METHODS

Study Area

Morris Wetland Management District (Morris WMD), a land management office of the U.S. Fish and Wildlife Service’s National Wildlife Refuge System, was established in 1964
to preserve habitat for breeding waterfowl in the Prairie Pothole Region of west-central Minnesota. At the time of this analysis, Morris WMD managed 245 separate parcels of federally-owned waterfowl production areas (WPA) spread across eight west-central Minnesota counties (Figure 1). These WPAs total over 21,000 hectares (ha) and range in size from approximately three to 500 ha. Morris WMD also administers over 14,000 ha of privately owned wetlands and grasslands protected by permanent conservation easements. The district is located in the Prairie Parkland Province and was historically dominated by tallgrass prairie.

The region has a level to rolling topography and a highly seasonal climate (MNDNR 2005). Much of the land within the district has been converted to agricultural use, which has resulted in a substantial loss and fragmentation of natural prairie and wetland ecosystems (Oslund et al. 2010).
MANAGEMENT PRIORITIZATION CRITERIA

The habitat goals and objectives for Morris WMD can be grouped into five main conservation priorities: breeding waterfowl, grassland birds, remnant tallgrass prairie, prairie wetlands, and threatened and endangered species. These priorities drive habitat management decisions at Morris WMD (USFWS 2012). Ideally, each conservation priority could be maximized within a single management framework. However, not all objectives can be equally met at every WPA (e.g., some landscapes have very little remnant prairie remaining, but do have sufficient restored wetlands and grasslands to support breeding waterfowl). It may not be economically or ecologically possible to manage a WPA according to a specific conservation priority. Therefore, it is important to be able to rank each unit according to a suite of often divergent conservation priorities.

To develop models that could objectively assess the value of each land parcel managed by Morris WMD, we met with Morris WMD staff and conservation partners to define the variables determined to be most directly related to the given conservation priorities. Our conservation prioritization scheme was premised on developing models derived from input variables that represented factors that could be directly influenced by management actions. Therefore we did not include variables in our models that could not be altered using management activities employed by the district (e.g., soil type). The input variables we chose were also directly related to specific conservation goals within Morris WMD (USFWS 2012), ensuring that our model results were placed in the context of tangible management goals and actions. Variables were required to have sufficient spatial coverage for the entire WMD. Potential variables that were identified but ultimately not used in the models included the current condition/status of the WPA (recovery versus maintenance phase) and seed harvest potential. These were not included because they were determined to be more accurately used as a non-biological constraint that would influence management decisions on an annual basis. As a result of this expert consensus process, ten variables were identified to include in our final set and are described in detail in the following sections.

Duck Pair Potential

The ability of a WPA to support breeding waterfowl is directly related to Morris WMD’s waterfowl production objective. We used breeding pair accessibility data from the USFWS Habitat and Population Evaluation Team to quantify the number of duck pairs that may be able to use specific habitats in a WPA (USFWS). These data were produced from long-term survey data and estimate the number of duck pairs (mallard [Anas platyrhynchos], blue-winged teal [Anas discors], gadwall [Anas strepera], northern pintail [Anas acuta], and northern shoveler [Anas clypeata]) that could potentially nest in upland habitats of every 16-ha block of the Prairie Pothole Region of Minnesota and Iowa (Quamen 2007). These estimates are based on known maximum distances of nest sites to wetlands and generalized linear regression models predicting the number of pairs that will use a given wetland during a typical nesting season (see Quamen 2007 for more information). Mean duck pair potential values on individual WPAs ranged from 9 to 175 pairs/km².

Percent Grass

The amount of grassland within the landscape in and around a WPA influences Morris WMD’s waterfowl production and native prairie objectives. Waterfowl nest success is higher in landscapes with more grassland cover (Ball 1995, Reynolds 2001, Horn et al. 2005). Managers understand that native prairie situated in an intact, non-native grassland landscape will have better ecosystem function and resiliency than will prairies surrounded by woodland (tree invasion) or cropland (pesticide drift, noxious weed invasion). We used an estimate of the percentage of grassland in the landscape provided by the USFWS Habitat and Population Evaluation Team. Based on remotely sensed imagery (Landsat Thematic Mapper) coupled with image classification techniques and ground-truthing efforts, these data estimate the percent of a nesting mallard’s home range (2-mile radius around each raster cell) that is grassland. Mean percent grass model scores for individual WPAs ranged from 0 to 63.4%.
Percent Upland Habitat

The proportion of a WPA's habitat comprised of or consisting of upland habitat (non-wetland natural vegetation) is important for waterfowl production and grassland birds. Breeding waterfowl require a balance of upland and wetland habitats in their home range; USFWS guidelines for acquiring WPAs recommend an upland to wetland habitat ratio of approximately 4:1 (USFWS 2003). Wetland habitat is relatively less important for grassland birds, and ratios up to 8:1 are thought to favor many species in this guild (Diane Granfors USFWS, unpublished data). We used an estimate of the total percentage of each WPA in upland habitat provided by Morris WMD. The percent upland habitat on WPAs in Morris WMD ranged from 0 to 98.7%.

Wetland Diversity

All WPAs include at least one wetland. WPAs with a diversity of wetland types will have a greater benefit for waterfowl production and for general wetland ecosystem integrity. Waterfowl use of different wetland types varies by species and by reproductive stage (Kantrud and Stewart 1977, Krapu et al. 1997). A diversity of wetlands will support higher species richness than does a single, isolated wetland (Brown and Dinsmore 1986, Naugle et al. 1999). Wetlands within each WPA were classified by Morris WMD as one of four types reflecting the seasonal permanence of standing water in the basin (temporary, seasonal, semi-permanent, or permanent; Cowardin et al. 1979). Wetland diversity within an individual WPA varied from 1 to 4 types. The relative amount of each wetland type within each WPA was not identified as a priority by Morris WMD staff and thus was not included in this study.

WPA Complex Size

Larger habitat patches can improve nest success for waterfowl and other grassland birds, largely because the predator community and foraging behavior is influenced by patch size (Horn et al. 2005, Herkert et al. 2003, Reynolds et al. 2001). Logistically, larger WPAs or WPA complexes improve management efficiency by increasing the overall habitat base for which a single management staff has control. WPAs are commonly purchased from multiple landowners over the course of several years, and sometimes previously isolated WPAs are connected to form a larger WPA complex. Of the 245 WPAs, 34 were part of a complex comprised of two or more WPAs (14 sets of two and two sets of three). Because adjacent WPAs are managed as a single unit, we calculated the total size of each WPA complex by consolidating all WPAs within 25 m of each other. This distance was selected to account for WPAs separated by roadways yet considered adjacent for this analysis. The WPA complex size ranged from 2.7 to 809.6 ha.

Effective Conservation Area

Often, a WPA will be geographically positioned adjacent to other permanent conservation lands. As with WPA complex size, this effective conservation area is important to Morris WMD's management objectives because of the increased conservation benefit provided by a larger, contiguous area. We calculated the effective conservation area for each WPA by adding the size of each WPA complex to the size of any adjacent permanent conservation lands, regardless of ownership or management. This included areas protected by the Minnesota Department of Natural Resources (scientific and natural areas, wildlife management areas, native prairie bank easements, state parks), Minnesota Board of Soil and Water Resources (Reinvest in Minnesota easements), United States Department of Agriculture (Wetlands Reserve Program), The Nature Conservancy, and USFWS (National Wildlife Refuges, habitat protection easements). The effective conservation area of WPAs ranged from 2.7 to 20,058 ha.

Remnant Prairie Size

Remnant prairie is rare in Minnesota, so any site with prairie is important for Morris WMD’s native tallgrass prairie conservation objective. While small tracts of remnant prairie undoubtedly provide reservoirs for some biological diversity, larger tracts are more likely to contain a functioning prairie ecosystem (MN Prairie Plan Working Group 2011), including supporting waterfowl and grassland birds. The total area within each WPA that was remnant, native prairie was provided by Morris WMD, and ranged from 0 to 256 ha.
Proximity to Human Development

A WPA's proximity to areas of high human activity and development (major roads, towns) will influence its potential to meet the district's breeding waterfowl and grassland bird objectives. Roads affect wildlife in several ways, including both direct mortality (i.e., road kill) and avoidance due to increased noise levels (see Forman and Alexander 1998 for a review of road effects). Proximity to towns may result in similar impacts due to increased recreational activity (e.g., dog walking; Miller et al. 2001), noise levels, and predation. We calculated proximity to human development as the Euclidian distance of a WPA boundary to either a major road or city. It would be impossible to identify a single buffer value appropriate for all of Morris WMD's priority species and little research on this topic has been conducted in our region. The WPAs in Morris WMD are typically located in highly fragmented landscapes; we used our best professional judgment in determining that negative effects of human development dissipate with a distance of over 3.2 km (2 miles). Municipal boundaries and road features were obtained from the Environmental Systems Research Institute (2005).

Grassland Bird Suitability

A WPA's suitability for grassland birds relates directly to Morris WMD's grassland bird objective. We obtained habitat suitability for grassland bird data (sedge wren [Cistothorus platensis], grasshopper sparrow [Ammodramus savannarum], Le Conte's sparrow [Ammodramus leconteii], savannah sparrow [Passerculus sandwichensis], bobolink [Dolichonyx pryzivorous], dickcissel [Spiza americana]) from Quamen (2007), who estimated suitability as the density of breeding pairs per 16-ha blocks of grassland area using predictive habitat models. Bird density was only calculated for grassland blocks > 1 ha in size. Mean values for this variable within WPAs ranged from 0.1 to 39.3 nesting pairs per 16 ha.

Percent Natural Wetlands

Johnson et al. (2008) estimated that in the counties that comprise Morris WMD, about 50% of the wetland area, and about 90% of individual wetland basins were drained. According to district staff, a WPA with a greater proportion of natural wetlands – those that have never been drained – will help the district meet its prairie wetland ecosystem objective. Natural wetlands have inherent value as a rare ecosystem, and are more likely than restored wetlands to have an intact plant community (Galatowitsch and van der Valk 1996). We calculated the percentage of wetlands within each WPA that were natural (i.e., no evidence of previous draining or ditching) using data from the USFWS National Wetland Inventory (USFWS 2010) due to a lack of field data. The proportion of natural wetlands on WPAs ranged from 0 to 100%.

CONSERVATION OBJECTIVE MODELS

Prior to developing our models, we reclassified and standardized our 10 input variables into integer values ranging from 0 to 100, with higher scores given to the preferred attribute. With the exception of wetland diversity, all variables were reclassified using an equal-interval approach with 100 bins to ensure comparability among variables. For wetland diversity, if at least three different wetland types occurred within a WPA the wetland diversity variable was given a value of 100, otherwise it was given a value of 0. The largest effective conservation area was a significant outlier (20,058 ha), therefore all values were scaled relative to the second largest value (1,140 ha) in order to reduce the influence of this single area. With respect to the proximity to human development input criteria, distances that were greater than 3.2 km were assigned a uniform score of 100, while WPAs within 3.2 km were given a value based on their relative distance to the human development feature. The closer the human development feature, the lower the score for that criteria.

We developed separate models for each of the five conservation objectives for Morris WMD. Within each objective, variables were selected and subsequently weighted based on their importance to achieving the desired conservation outcome (maximization of a conservation priority), with the stipulation that within each model all weights must sum to 1 to account for different variable sets in each model. Weighting was based on expert opinion provided by Morris WMD staff (Table 1). Final input variable values were taken as the product of the reclassified value and the variable weight for each specific conservation objective. Model values were then calculated for each WPA.
using spatial overlays of each weighted variable (Figure 2). Variables and weights for four of the five models — breeding waterfowl, grassland birds, tallgrass prairie, and prairie wetland ecosystem — are given in Table 1.

For our threatened and endangered (T & E) species model, variables and weights were based on observed occurrences of threatened and endangered species. We used data from the Minnesota Natural Heritage Information System (MNHIS; MNDNR 2009) to identify 12 Federal or State listed T & E species known to occur within our study area (Loggerhead shrike [Lanius ludovicianus], Dakota skipper [Hesperia dacote], Hair-like beak-rush [Rhynchospora capillacea], Mucket [Actinonaias ligamentina], Short-pointed umbrella-sedge [Cyperus acuminatus], Wilson’s phalarope [Phalaropus tricolor], Elktoe [Alasmidonta marginata], Sterile sedge [Carex sterilis], Yellow prairie violet [Viola nuttallii], Eared false foxglove [Agalinis auriculate], Lichen [Buellia nigra], Chestnut-collared longspur [Calcarius ornatus]).

The MNHIS dataset does not represent the results of a comprehensive survey for all species that are listed, but is the most extensive spatial data available. To ensure we were being as inclusive as possible, we then extracted all occurrences of our target species in the MNHIS database that were within 1.6 km (1 mile) of a WPA. At each occurrence we then calculated the Euclidian distance of all raster cells to the occurrence location up to 1.6 km. We then normalized these distances from 0 to 100, with 100 being given to the cell in which the species occurred and 0 being given to cells at least 1.6 km distant. Normalization was done to remain consistent with other input criteria since the T & E score can be used within the conservation objective model decision support tool. We then calculated the average value for each cell using raster surfaces for all 12 species and took the mean value of these cells from within the WPA boundary as our model score.

### Overall Prioritization Model

We created an overall prioritization model for each WPA based on the scores from each of the five individual conservation objective models. In this case we used an equal weighting scheme such that the scores from the five individual conservation objective models each had a weight of 0.2, thus each objective received equal weighting in our example. In practice, certain objectives may require higher weights than others based on management direction or to account for non-independence among objectives. Such alternative weighting schemes could be readily implemented using our Custom Weighting Tools.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Model structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breeding Waterfowl</td>
<td>[S = 0.17(\text{duck}) + 0.17(\text{grass}) + 0.12(\text{upland}) + 0.08(\text{wetland}) + 0.12(\text{area}) + 0.08(\text{size}) + 0.12(\text{prairie}) + 0.12(\text{human})]</td>
</tr>
<tr>
<td>Grassland Birds</td>
<td>[S = 0.19(\text{bird}) + 0.16(\text{upland}) + 0.14(\text{area}) + 0.19(\text{size}) + 0.16(\text{prairie}) + 0.16(\text{human})]</td>
</tr>
<tr>
<td>Tallgrass Prairie</td>
<td>[S = 0.18(\text{grass}) + 0.22(\text{area}) + 0.30(\text{size}) + 0.30(\text{prairie})]</td>
</tr>
<tr>
<td>Prairie Wetland Ecosystem</td>
<td>[S = 0.30(\text{wetland}) + 0.22(\text{area}) + 0.30(\text{size}) + 0.18(\text{natural})]</td>
</tr>
</tbody>
</table>
Figure 2: Example of spatial overlay procedure with variable weighting to determine final model score. For each variable: 
\[ a = \text{transformed variable score}, \quad b = \text{variable weight}, \quad c = \text{weighted score}. \]
The sum of all "c" values gives the final model score for the WPA.

- **Percent Upland**
  \[ 90.85 (a) \times 0.16 (b) = 14.54 (c) \]
- **Remnant Prairie Size**
  \[ 46.81 (a) \times 0.16 (b) = 7.49 (c) \]
- **Effective Conservation Area Size**
  \[ 79.72 (a) \times 0.14 (b) = 11.16 (c) \]
- **Grassland Bird Suitability Model**
  \[ 51.47 (a) \times 0.19 (b) = 9.78 (c) \]
- **Proximity to Development**
  \[ 87.12 (a) \times 0.16 (b) = 13.94 (c) \]
- **WPA Complex Size**
  \[ 19.93 (a) \times 0.19 (b) = 3.79 (c) \]

**Grassland Birds Model Output (Twin Lakes WPA example)**
\[ (14.54 + 7.49 + 11.16 + 9.78 + 13.94 + 3.79) = \boxed{60.70} \]
Custom Weighting Tools

Because our primary objective was to provide Morris WMD with dynamic conservation planning tools for evaluating conservation priorities, we developed two custom weighting tools using Microsoft Access and Visual Basic (VBA) to allow for user-defined weighting schemes to be applied (Figure 3). First, we developed an interactive tool allowing the user to redefine the conservation objective model weights used in the overall prioritization model. Second, we developed an interactive tool allowing the user to develop customized conservation objective models using variables and variable weights of the user’s choice. Both tools are available for download (http://www.umesc.usgs.gov/management/dss/morris_wmd.html). These tools allow staff at Morris WMD to develop new models and prioritizations using the assembled data sets in the event that management objectives and priorities change.

Figure 3: Screen captures of custom weighting tools developed for Morris Wetland Management District.
Table 2: Overall prioritization and individual conservation objective model scores for ten WPAs with highest overall model score. Scores of individual conservation objective models were normalized to range from 0 to 100. *Based on all 245 WPA units.

<table>
<thead>
<tr>
<th>WPA Name</th>
<th>Overall score</th>
<th>T &amp; E</th>
<th>Breeding Waterfowl</th>
<th>Grassland Birds</th>
<th>Tallgrass Prairie</th>
<th>Prairie Wetland Ecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hegland</td>
<td>90.8</td>
<td>84.8</td>
<td>95.7</td>
<td>90.8</td>
<td>84.9</td>
<td>97.9</td>
</tr>
<tr>
<td>Hastad</td>
<td>86.8</td>
<td>48.9</td>
<td>98.2</td>
<td>100.0</td>
<td>100.0</td>
<td>87.0</td>
</tr>
<tr>
<td>Prairie</td>
<td>68.2</td>
<td>74.8</td>
<td>86.1</td>
<td>70.2</td>
<td>40.3</td>
<td>69.4</td>
</tr>
<tr>
<td>Mosquito Ranch</td>
<td>67.8</td>
<td>0.0</td>
<td>100.0</td>
<td>79.3</td>
<td>59.8</td>
<td>100.0</td>
</tr>
<tr>
<td>Loen</td>
<td>66.6</td>
<td>0.0</td>
<td>92.8</td>
<td>88.1</td>
<td>65.6</td>
<td>86.3</td>
</tr>
<tr>
<td>Svor</td>
<td>65.7</td>
<td>0.0</td>
<td>91.5</td>
<td>83.6</td>
<td>65.5</td>
<td>88.1</td>
</tr>
<tr>
<td>Robin Hood</td>
<td>64.7</td>
<td>0.0</td>
<td>87.4</td>
<td>70.1</td>
<td>66.9</td>
<td>99.3</td>
</tr>
<tr>
<td>Overby</td>
<td>62.2</td>
<td>41.8</td>
<td>74.6</td>
<td>50.5</td>
<td>54.8</td>
<td>89.3</td>
</tr>
<tr>
<td>Twin Lakes</td>
<td>57.7</td>
<td>10.2</td>
<td>83.2</td>
<td>79.0</td>
<td>53.3</td>
<td>63.0</td>
</tr>
<tr>
<td>Blue Mounds</td>
<td>56.6</td>
<td>0.6</td>
<td>88.9</td>
<td>70.1</td>
<td>46.6</td>
<td>77.0</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>25.6</strong></td>
<td><strong>4.5</strong></td>
<td><strong>38.3</strong></td>
<td><strong>27.9</strong></td>
<td><strong>13.9</strong></td>
<td><strong>43.2</strong></td>
</tr>
<tr>
<td><strong>Range of raw scores</strong></td>
<td><strong>3.9–90.8</strong></td>
<td><strong>0–100</strong></td>
<td><strong>11.4–68.3</strong></td>
<td><strong>8.6–74.6</strong></td>
<td><strong>0.4–83.4</strong></td>
<td><strong>7.7–85.2</strong></td>
</tr>
</tbody>
</table>

RESULTS

Among the overall prioritization and conservation objective models, average scores across all WPAs varied substantially. Table 2 displays the results for the top ten WPAs ranked by a substantially lower average score than any other model (Table 2). There was also substantial variability in model scores among WPAs. Several WPAs were consistently among the highest scoring for each conservation objective model (Table 2), likely due to their high scores for variables that were largely ubiquitous among conservation objective models such as WPA size and effective conservation area. Conversely, some individual WPAs exhibited substantial overall model score. The scores for all WPAs are available from the website [http://www.umesc.usgs.gov/management/dss/morris_wmd.html](http://www.umesc.usgs.gov/management/dss/morris_wmd.html). The prairie wetland ecosystem model had the highest average score followed by the breeding waterfowl model, with the T & E model having variability among conservation objective models. For example, Overby WPA had the lowest score among the top ten overall WPAs for both the breeding waterfowl and grassland birds objectives, yet ranked fourth highest for the prairie wetland ecosystem objective (Table 2). Variability in conservation objective model scores among WPAs also manifested spatially, with no obvious spatial patterns evident (Figure 4).
Figure 4: Maps depicting the relative scores of each waterfowl production area (WPA) for each conservation objective model and also the overall WPA prioritization model. The top ten highest ranked WPAs are labeled in each panel.
DISCUSSION

Conservation planning tools are in place for numerous other landscape-level conservation ventures (e.g., Lynch and Taylor 2010). However, there are comparatively few that concomitantly address multiple conservation objectives as ours does. Our approach also differs from many applications of conservation planning tools in that: 1) Morris WMD management staff were directly involved with model development so that variables and objectives were directly relevant to potential management decisions and 2) by using a Geographic Information System to develop comprehensive landscape-scale datasets, we were able to accommodate the spatially dispersed nature of the conservation units within our study area. This approach has the added benefit of providing a level of transparency to Morris WMD management decisions by clearly linking management decisions with conservation objectives. Our approach is not without its limitations. For example, reliance on expert opinion, though transparent, is a subjective method for defining variables. However, our prioritization tool has the capacity to incorporate weighting schemes developed through the analysis of empirical data, which we suggest would be an important step towards developing an approach to conservation prioritization that is transparent and free of subjectivity.

We found that prairie wetland ecosystem and breeding waterfowl were the two highest scoring objectives. This is encouraging given the nature of our study area (waterfowl production areas were originally authorized as a means to protect small wetlands across the landscape for the purposes of waterfowl production), and suggests that our ranking approach is relevant to the conservation goals identified for this setting. Our results also highlight the utility of evaluating individual habitat conservation units for their potential effectiveness for certain conservation objectives. For example, Mosquito Ranch WPA had a score of 0 for our T & E model, indicating it has limited utility for preserving threatened or endangered wildlife. However, this WPA scored 100 for both the breeding waterfowl and prairie wetland ecosystem models, demonstrating it clearly has conservation value, but that value is contingent upon the specific conservation objective. Conversely, some WPAs scored low in all models, in which case the management agency may need to decide whether limited conservation resources should be allocated to these units at all (Marris 2007). The issue of balancing multiple conservation objectives is non-trivial, and can be challenging to address with applied conservation programs (Bode et al. 2011). Our approach to identifying the value of each unique habitat unit helps to alleviate this issue by allowing prioritization of different objectives on different spatial units within a greater network of habitat units. Obviously, this approach is most readily applicable to study areas such as ours that are characterized by numerous and spatially dispersed units as opposed to single units. However, the general principle can be applied to larger, continuous areas through separation of the landscape into relevant management units (e.g., watersheds, forest stands).

Although our prioritization approach focused on protected lands, it could easily be extended to adjacent private lands to further evaluate the potential outcomes of conservation actions beyond the spatial boundaries of the WPAs within the Morris WMD (Ciuzio et al. 2013). Indeed, our prioritization approach could be readily modified to account for private landowner conservation objectives and capacity (e.g., Moon and Cocklin 2011), creating a flexible tool that could be applied to both public and private lands conservation prioritization. We suggest future efforts could focus explicitly on the incorporation of private lands into conservation prioritization strategies due to its potential influence on wildlife populations (Thogmartin and Rohweder 2009, Seigel and Lockwood 2010).

Outputs from the overall prioritization model are particularly useful to the Morris WMD and are currently being used by district staff to prioritize which WPAs receive management resources. A particularly valuable exercise for WMD staff has been to group WPAs into management categories based upon their overall model scores relative to other WPAs. Those grouped into a high priority category are expected to receive the bulk of the available resources of the WMD. Those WPAs grouped into a medium priority category will get some attention but logistics (distance to WPA, amount of work needed) will strongly influence resource investment. Finally, those WPAs falling into a low priority category will receive very little or no resource investment from the WMD. Additionally, Morris WMD gives greater management emphasis to habitat easements and Partners for Fish and Wildlife projects that are adjacent to WPAs with higher overall model scores. Applying these models to private lands within the Morris WMD could identify
those lands with the greatest potential conservation value to allow prioritization of habitat easements and Partners for Fish and Wildlife projects. Although the exact nature of our models is specific to our study area, we believe the general framework is applicable in many situations and that the models we developed may serve other areas with similar conservation objectives.

Our models do not explicitly guide conservation planning efforts, but rather provide a means of identifying the maximum conservation gains possible within the priorities developed by Morris WMD. A next step would be to link these tools for quantifying the potential conservation value to cost estimates for managing these habitat units. This would place conservation planners in a position to transparently and objectively prioritize conservation actions.

Our models are but one example of the ways in which conservation planning can be aided by the application of robust conservation planning tools. Developing tools that can be utilized by conservation managers is an important step towards building transparent and objective management strategies. Future efforts aimed at improving the decision making process in conservation management could beneficially emphasize the use of practical tools that reduce the reliance on subjective decision making.

Our interactive tools (Figure 3) allow the user to redefine the specific variables used for each conservation objective model and how the relative weight of each variable influences the output model score. These tools have an easy to use graphical user interface and provide the option to export modeled results as Excel spreadsheets that can be linked to the WPA spatial data set within a Geographic Information System.

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