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RESEARCH

A Riparian Wildlife Habitat Evaluation Scheme Developed Using GIS

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ABSTRACT / To evaluate riparian habitat for wildlife, we used a geographic information system (GIS) that prioritized individual streams (for acquisition or management) by habitat ranking. We demonstrate this methodology for the Vermilion River basin in east-central Illinois, USA. Three data sets were used to evaluate land cover encompassing 300 m on either side of the streams: (1) the US Geological Survey's land use and land cover information (LUDA), (2) land cover manually digitized from the National High Altitude Photography (NHAP) program, and (3) Landsat Thematic Mapper (TM) data classified into land cover. Each of 30 tributaries in the study area was ranked for habitat according to the data contained in each data set, and results were compared. Habitat ranking schemes were devised and analysis performed for three species guilds: forest, grassland, and mixed successional species. TM and NHAP each differentiated habitat scores (for forest, grassland, and mixed successional guilds) among tributaries in a similar and suitable way, while LUDA was not suitable, due to the coarse resolution of the data. Overall, it was shown that the methodology is suitable to rank streams based on riparian habitat quality. Even though more work is needed to test and verify the method, the project has shown the potential for such techniques to assist in evaluating, tracking, and improving the management of riparian wildlife resources. The method can easily be applied over large areas such as states if TM-based land cover and stream data are available.

In the late 1970s, the President's Council on Environmental Quality (1978) estimated that as much as 70% of riparian ecosystems (systems adjacent to streams and rivers) present at the time of European colonization in the United States had been destroyed. Presently, evidence continues to mount on the extremely high value that riparian systems provide in ecosystem services (Forman 1995); protection of water quality as filters (Welsch 1991, Gilliam 1994), biodiversity/habitat (Naiman et al. 1993), conduits for dispersal (Hanson et al. 1990, Harris and Scheck 1991), sinks, and sources.

KEY WORDS: Landscape ecology; Riparian habitat; Wildlife habitat; GIS; Illinois; Spatial analysis

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Illinois is a highly developed state with less than 11% of its area in its "potential" vegetation type (Klopatek et al. 1979). Although large in size (142,000 km^2), agriculture and urbanization dominate the state, and only a small percentage of the state can be considered high quality for wildlife (Iverson et al. 1989). Illinois contains in excess of 21,200 linear km of streams and rivers (Neely and Heister 1987). The majority is characterized by their low gradient and was historically connected to expansive floodplain areas of high-quality wetland, forest, and grassland habitats. Subsequent channelization, artificial draining, and leveeing effectively isolated the fertile floodplain from the stream channels leading to the decimation of much of the native habitats throughout the state (e.g., Osborne et al. 1991). Similar, or even greater losses of forests and wetlands have been documented across Illinois (Iverson and Risser 1987; Iverson et al. 1989, Havera and Suloway 1994), and land conversion continues, especially in the south-central portion of the state (Osborne et al. 1991, Iverson 1994). The loss of wildlife habitat has been documented in Illinois and has reached a critical stage (Illinois Wildlife Habitat Commission 1985, Havera and Suloway 1994).

Remaining riparian areas comprise a significant portion of the remnant forested vegetation in the state. In fact, for the south-central portion of the state, 79% of the forest land is within 300 m of the streams (Iverson 1994). This pattern is primarily due to residuals remaining because of the historical difficulty of growing row crops economically on the steeper slopes associated with many of the stream and river valleys (Iverson 1988). Thus, information on the location and extent of these important vestiges of native Illinois is critical for the successful management and protection of riparian habitats. In Illinois, this is complicated not only by the state's size, but also by the geographical variability that exists from north to south, and most importantly, by economic constraints. It is imperative that resource managers maximize the use and application of information that may reside in statewide databases to identify these vital riparian habitats. The objectives of this study were to: (1) identify riparian wildlife habitats along streams in the Vermilion River basin located in east-central Illinois using applicable and available data sources; (2) develop and assess methodologies to identify riparian habitats of different qualities in the Vermilion River basin using these data sources; and (3) compare the results of these methods to identify quality riparian wildlife habitats throughout the state and beyond.

Materials and Methods

Study Area

This study was conducted on the Salt Fork and Middle Fork branches of the Vermilion River (tributary to the Wabash River) located in east-central Illinois (Figure 1). Within these watersheds, a total of 30 streams drain an area of at least 10 sq mi (25.8 km^2). The Vermilion River basin has a long history of scientific investigation because of its close proximity to the University of Illinois and the Illinois Natural History Survey. Many detailed descriptions of the history, geography, soils, climate, land use, and aquatic fauna have been reported (for example, Osborne and Wiley 1988; Wiley et al. 1990; Osborne et al. 1991; Tazik et al. 1991).

Methodology

The Illinois Geographic Information System (IGIS) was the primary tool used to perform the work described here. By incorporating a spatial component into the data sets, the IGIS made it possible to combine and compare various data sets, evaluate the characterization of streams relative to wildlife habitat, and generate maps and tabular data for statistical analysis and display. Several data sets were available for analysis and evaluation (Table 1).

Many of the data sets used in the study are subsets of larger, statewide coverages. Others are regional, covering only the Vermilion basin, as in this investigation. Data sets differ in scale, temporality, and in the degree of processing that is necessary to use them. All images (photographic or satellite) were based on data collected within a decade, 1978–1988, to minimize temporal variation. This basin is largely rural and is not undergoing rapid urbanization relative to some other parts of the state and country. Different coding schemes were normalized so that data generated through spatial processing of the various data sets could be statistically compared.

Land and Stream Data Set Description and Derivation

Digital line graph. Primary among the digital cartographic products produced by the US Geological Service (USGS) are the digital line graph (DLG) files (Table 1). The 1:100,000-scale hydrographic layer of the DLG files for all of Illinois resides on the IGIS and comprises the most detailed representation of the streams and lakes available for the whole state. The USGS produced these data by digitizing a photographically reduced composite of the hydrographic layer from the 1:24,000 USGS base map series. The data carry codes identifying the type of feature represented, such as stream or shoreline and descriptive information such as flow (for example, intermittent) or spatial location (for example, right bank) (US Department of the Interior and US Geological Survey 1989).

The data pertinent to the study area were extracted and modified for use in this project. This effort involved edge matching to make the data topologically consistent and then extracting only those streams with at least 10 square miles of drainage area.

Land use and data analysis. The USGS Land Use and Data Analysis (LUDA) data set contained within the IGIS represents land use and land cover for all of Illinois. LUDA is based on a hierarchical classification system developed nationally by the USGS for use with remote sensor data (Anderson et al. 1976). The USGS derived land use and cover by conventional interpretation of high-altitude color-infrared photographs onto base maps at a scale of 1:250,000.

Data for the study area were extracted from this data

Figure 1. Stream names (with >10 mi^2 drainage) for the Salt Fork and Middle Fork branches of the Vermilion River, along with a 300-m buffer, as derived from 1:100,000 DLG data.

Table 1. Summary of data sets used in this study[a]

Data Sets	Date	Scale/ resolution	Type	Source
Stream Network				
DLG hydrology	Varies	1:100,000	Arc coverage	USGS 1:24,000 base map series
Land cover				
LUDA	1978, 1881	1:250,000	Arc coverage	Aerial photography
NHAP	1981–1983	1:24,000	Arc coverage	Aerial photography
Landsat imagery	1988	30 meters	Erdas file	Landsat thematic mapper
NWI	1981, 1983	1:24,000	Arc coverage	Aerial photography, 58,000-altitude
INAI	Varies	1:24,000	Arc coverage	Illinois Department of Conservation
Other				
Drainage basin boundary	Varies	1:24,000	Arc coverage	USGS WRD drainage basin area files
Public land survey sections	Varies	1:24,000	Arc coverage	USGS 7.5- and 15-minute base maps

[a]See text for data descriptions.

Table 2. Land use and cover categories for LUDA and NHAP data[a]

Level I	LUDA/NHAP code	Corresponding LUDA/NHAP category
Agriculture	211	Inactive cropland
	213	Active cropland
	23	Confined feeding operations
	24	Other agricultural land
	21	Cropland
Grassland	212	Active pastureland
	172	Landfill sites (closed sanitary)
	62	Grassland wetland
Forest	411	Riparian vegetation (trees)
	413	Deciduous forest with housing
	414	Forested wetland (reclaimed strip)
	415	Deciduous forest (reclaimed strip)
	416	Riparian forest (reclaimed strip)
	61	Forested wetland
Mixed successional	22	Orchards, nurseries, and horticulture areas
	44	Secondary growth (shrubs, etc.)
	412	Riparian vegetation (grassland/shrubs)
Urban	11	Residential
	12	Commercial and services
	13	Industrial
	14	Transportation, communication, and utilities
	15	Industrial and commercial complexes
	16	Mixed urban and built-up areas
	17	Other urban and built-up lands

[a]Level II codes used in LUDA are presented as the first two digits, while three digits represent level III codes used in NHAP.

set. They date from 1978 (Peoria 1:250,000 quadrangle) and 1981 (Danville 1:250,000 quadrangle). Two levels of classification were used in the study. Level I consists of nine categories, six of which occur in Illinois: urban or built-up, agricultural, forest, water, wetland, and barren. Level II further subdivides each of these categories; these classes are presented as the first two digits in the LUDA codes in Table 2.

National High Altitude Photography program. Land use and cover patterns for the study area were derived from the National High Altitude Photography (NHAP) program. Similar to LUDA, the land use and cover information was determined by interpreting high-altitude color-infrared photographs, only the classes were mapped at a much finer scale (1:24,000 for NHAP vs 1:250,000 for LUDA). The NHAP photographs (1:20,000 scale; film exposure 1981–1983) were obtained from the US Department of the Interior, EROS Data Center in Sioux Falls, South Dakota. Land use and cover patterns were interpreted and digitized as described in detail in Osborne and Wiley (1988). The land use and cover classification system employed consisted of a modified version of the LUDA system (Anderson et al. 1976), which is generally considered to be resource oriented (see codes and categories, Table 2).

Landsat Thematic Mapper. Landsat Thematic Mapper (TM) satellite data were used to assess land cover for a majority of the watershed study area. The satellite collected the data on 27 June, 1988 and the data have a spatial resolution of about 30 m × 30 m per pixel. The configuration used for this study was ERDAS, Inc. image processing software, running on a Unix workstation.

Geographic reference was established to an accuracy of within half a pixel (approximately 15 m) using 60 ground control points. The study area boundary was used to clip the TM data to create a file containing TM data for the study area only. The TM scene used for this study covered all except about 19,000 ha (8%) of the eastern portion of the watershed study area.

The TM data were classified into land cover types using unsupervised classification. The resulting clusters were assessed for their spatial distribution and, with the aid of aerial photographs and quadrangle maps, assigned to land cover types. In most situations, many clusters were grouped together to represent one land cover type.

National Wetlands Inventory. Wetland data for the Vermilion River basin were taken from the statewide National Wetlands Inventory (NWI), which resides within the IGIS. The NWI, developed by the US Fish and Wildlife Service (Cowardin et al. 1979), is based on aerial photography from an altitude of 58,000 ft. The photographs were manually interpreted and transcribed to the USGS 1:24,000 base map series. The photography for the Vermilion basin was taken in the spring and fall of 1981 and 1983. No differentiation among wetland types was made for this study.

Illinois natural areas inventory and Illinois nature preserves. Natural areas and nature preserves data for the Vermilion basin were taken from the statewide Illinois Natural Areas Inventory (INAI) (White 1978). Data taken on field visits were used to digitize boundaries drawn on 1:24,000-scale quadrangle maps and low-altitude photography (8000 ft altitude). The areas identified are considered to have a unique biological or cultural value to the state but do not reflect any information on land ownership. The INAI data quite reliably depict the state's best 0.05% of land still existing in a natural or near-natural condition. Usually, the nature preserves, which are now protected by Illinois statute, are a subset to the INAI.

Analysis of Land Cover by Data Source

The USGS LUDA, the NHAP, and the classified Landsat TM coverages describe land cover throughout the entire Vermilion basin. For purposes of comparison and analysis, all of these data were overlain with the 300-m buffer of DLG stream segments. The land use and cover composition of the area within 300 m of each stream and for the entire study area were determined for each data set, as defined by that data set.

The percentage of area classified as wetlands, natural areas, and preserves within a 300-m buffer (600 m total width) was also determined for each of the 30 tributaries contained within the Vermilion River basin and for the entire basin.

Analysis of habitat by tributary

Wildlife habitat. Methods were developed to convert information among the data sets into estimates of value for wildlife habitat. These methods account for differences in how land use was coded among the data sets.

A principle purpose of this project was to identify areas of riparian wildlife habitat and the quality of those habitats. Habitat is considered to be species specific with regards to physical surroundings and prevailing environmental conditions. It is not realistic to attempt to identify the habitat of every wildlife species (bird, mammal, amphibian, insect, etc.) that occurs in Illinois; nor should it be necessary to do so from a management perspective. So, we use the term "habitat" in the generic sense as the habitat of a guild of species. The concept of guild was introduced by Root (1967) and refers to a group of organisms of the same taxocene that utilize a resource in a similar manner.

Selection of guild categories was limited by the land use and cover categories that comprised the original land use and cover classification systems (e.g., Anderson et al. 1967) used in each of the individual databases and by the level of resolution of the different data sets. Therefore, our goal was to encompass the largest number of wildlife species within the framework of these data constraints. We selected three fairly general guilds: forest, grassland, and mixed successional. The specific LUDA land use and cover codes that characterize each guild are shown in Table 2.

A general guide in conservation biology is that a species can be best protected and managed by managing the habitat (e.g., Graber and Graber 1976, Block and Brennan 1993, Block et al. 1994, Lindenmayer et al. 1994, Rich et al. 1994). Thus, using general habitat guilds would seem consistent with contemporary natural resource management philosophies. Example species from eastern Illinois for our three general guilds could be the gray squirrel (*Sciurus carolinensis*) and Swainson's warbler (*Limnothlypis swainsonii*) for forest, the 13-lined ground squirrel (*Spermophilus tridecemlineatus*) and grasshopper sparrow (*Ammodramus savannarum*) for grasslands, and white-tailed deer (*Odocoileus virginianus*) and red-winged blackbird (*Agelaius phoeniceus*) for mixed successional habitats.

Habitat rating by guild for LUDA, NHAP, and TM data. Our goal was to calculate tributary and bank-specific wildlife habitat indices from information in the LUDA, NHAP, and TM data sets. The percentage of each land cover type from the three data sets was calculated for each tributary as a percentage of the total area encompassed by a buffer extending 300 m either side of the stream. This relatively wide buffer distance was used for several reasons: (1) it matches the buffer for another related Illinois data base, the Illinois Streams Information System, so that general comparisons can be made; (2) it encompasses most of the forest in the state [79% of all forest lands in another watershed in southeastern Illinois fell within 300 m of streams (Iverson 1994)]; and (3) it ensures that the indices developed consider larger blocks of habitat, not just the habitat immediately adjacent to the streams. Percentage of land cover and the subsequent habitat ratings were developed for grassland, forest, and mixed successional wildlife guilds.

Development of such a system proceeded under the following constraints: (1) the rating system had to be applicable to land uses within 300 m of a major stream reach (0–300 m inclusive); (2) the rating system had to accommodate forest, grassland, and mixed successional wildlife species guilds; and (3) the system needed to be built with the imposed LUDA classes of land types (Table 2).

Once comprehensive and relatively concordant land use and cover categories were generated, a system for valuation of the proportion of riparian land cover within each category along each stream was developed. After examination of several potential procedures, we concluded that the following approach would be most appropriate for comparison. Evaluation of forest and grassland habitat was straightforward because of consistent classification among data types, whereas the mixed successional guild was addressed in a separate, more complicated fashion.

Valuation of forest and grassland habitat. The procedure uses interval measurements of land use and codes them. It assumes that no land uses other than forest and grassland, the primary land uses for defining and characterizing a species guild of interest, are of value or importance as wildlife habitat for the guilds in question. The initial step involves the determination of the proportion of each of the major land use and cover categories (Table 2) within each 300-m buffer of a tributary. Subsequently, a score of the relative quality of the riparian habitat (within 300 m of the stream) is calculated for each guild and for each tributary. The scoring system, which ranges from 0 (no habitat) to 5 (optimal habitat) in units of one tenth, is based upon the general ecological principle of species area curves, that the number of species inhabiting an area of a given habitat type is a function of the size of the area or amount of habitat. This relationship is generally assumed to be logarithmic in form as depicted in Figure 2A. The score does not depend on the area of individual patches within the 600-m strip, only the proportions of the land covers within that area for each tributary.

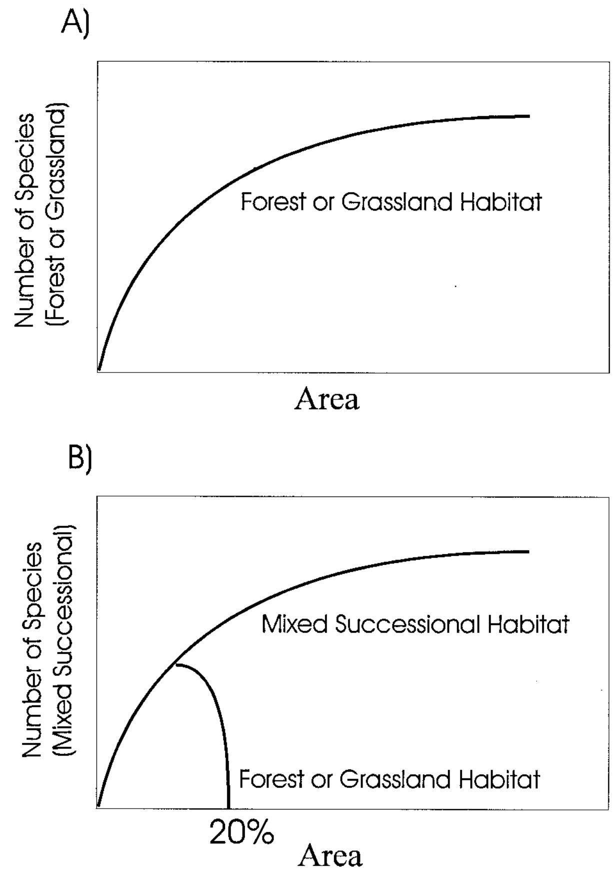

Figure 2. Theoretical relationships (i.e., species area curves) between the area of habitat and the number of species the area supports for (**A**) forest and grassland species, and (**B**) mixed successional species. **B**: the parabolic curve for forest and/or grassland indicates that these land covers contribute to mixed successional habitats when their respective cover proportions are ≤20% (e.g., they have significant amount of edge); beyond 20% cover, the forest or grassland cover does not contribute to the mixed successional habitat ranking.

Therefore, it assumes that habitat value of several smaller fragments is equal to that of a single patch of the same size (as found by McCoy and Mushinsky 1999).

Figure 2A was used as a model to generate the scoring procedures for grassland and forest species guilds. This scoring scenario assumed that the species richness of forest and grassland species increased as a function of the log of the size of the specific forest or grassland habitats. It also assumed that habitats that were composed of a minimum of 85% grassland or forest were optimal habitats for grassland and forest guild species (i.e., ≥85% received a score of 5).

Therefore equation 1 was adopted to calculate the habitat index score for the forest and grassland guilds.

$$rnd\,(HI) = [\log(PCT + 1)*5/\log(101)] + 0.15 \quad (1)$$

where *rnd* is a function that rounds the habitat index (*HI*) for the grassland or forest guild to the nearest tenth, and PCT is the percentage of forest or grassland land use (see Table 2 for pertinent land use codes). If the PCT is >85%, this formula will result in an *HI* value greater than 5. In such instances, the *rnd* function rounds all values back to a maximum *HI* value of 5. Equation 1 also dictates that the minimum value of *HI* is 0.15, not 0.

Procedure for mixed successional guild. Evaluation of mixed successional species is more complex. Although we used a mixed successional habitat land-use category (Table 2) and have assumed a logarithmic relationship between mixed successional species and the area of mixed successional habitat (Figure 2A), forest and grassland habitats may also be beneficial to the mixed successional habitat guild. The positive effects of the forest and grassland habitats are related to the beneficial effects of edges (boundaries between habitat types) and land-cover diversity that create appropriate habitats for this transitional guild. Too much forest or grassland habitat is likely to detract from the overall quality of the habitat for mixed successional species. For instance, we hypothesize that a range of 0%–20% of grassland and/or forest could be suitable for many mixed successional species. Of course, not all areas of grassland and forest habitats (Table 2) provide appropriate areas for mixed successional species; however, the peripheral margins would be expected to be most appropriate. Therefore, grassland and forest habitats should not be scaled the same (or worth as much from a quality perspective) as an equivalent amount of mixed successional habitats. A generalized model of this concept is depicted in Figure 2B. In essence, we would expect a dominant logarithmic relationship to exist between habitat quality and percentage of mixed successional land, and a subdominant parabolic-like relationship to exist between mixed successional species and both grassland and forest habitat within the range of 0%–20% of forest and/or grassland (Figure 2B). In our approach, we also consider the grassland and forest habitats within the range of 0%–20% to be of lesser value (i.e., half) than equivalent amounts of mixed successional habitats.

This approach is presented by the following equation that calculates a potential mixed successional habitat (PMSH):

$$\%\,PMSH = (\%\text{ mixed successional}) + [\%\text{ grassland } (\leq 20\%)/2] + [\%\text{ forest } (\leq 20\%)/2] \quad (2)$$

The *HI* value for mixed successional species is then calculated by substituting the percentage of PMSH into equation 1 for PCT. All other procedures are as previously described for equation 1 above.

Similar to procedures for determining the HI for forest and grassland guilds, the proportions of the total area within 300 m of the stream that are composed of mixed successional, grassland, and forest land use categories are calculated. If the grassland and/or forest categories individually comprise ≤20% of the total area of land, then half of their proportional area is added to the total proportion comprised of the mixed successional category (see equation 2) in determining the percentage of potential mixed successional habitat.

Equation 2 incorporates most, but not all, of the preceding concepts associated with the generalized model depicted in Figure 2B into a single and relatively simplistic scoring system. Although simple, the proposed model provides some interesting and pertinent hypotheses for future research and testing.

We reiterate that although calculations of HI utilize formal equations, the final values only represent our best educated guess of the quality of a land category of a certain area for a particular guild. The approach outlined above is still a Delphi procedure and should not be regarded as anything more powerful. Unfortunately, we were unable to field test these concepts or results in this study.

Table 3 provides representative HI values for mixed successional habitats that result from different combinations of mixed successional, grassland, and forest land cover combinations that were generated using the preceding method.

Comparisons, mapping and analysis of NHAP, LUDA and TM data sets. The methodologies described were applied to each of the 30 stream reaches in the Vermilion basin for each guild. For each tributary, this proce-

Table 3. Range of habitat index for mixed successional guild based on proportions of grassland, forest, and mixed successional habitats

Habitat index score	Land cover type (%)		
	Mixed successional	Forest	Grassland
0.9	1	0	0
2.2	1	5	5
2.9	5	3	10
3.4	7	1	25
3.2	10	5	5
3.8	20	1	15
4.2	35	10	5
4.3	40	4	4

dure allowed calculation of average habitat rating scores, which were plotted to visually display habitat for each guild by data set (NHAP, LUDA, and TM). Further, correlations among data sources were performed to assess relative performance of our rating schemes and the overall methodology. Spearman rank correlations (nonparametric) were run to compare the order of habitat rankings among the 30 tributaries, and Pearson product moment statistics were generated to assess similarities in actual habitat ratings.

Results and Discussion

Analysis of Land Cover by Data Source

We were interested to learn of the inherent differences and similarities among the data sets, apart from the rankings for habitat value. In this section, we report on the proportions of each tributary's 300-m buffer, as depicted by various data sets, contained in forest, grassland, mixed successional, agricultural, urban, wetlands, and natural areas. For comparison, we also report these proportions for the entire Vermillion River basin.

Assessment of LUDA, NHAP, and TM data sets. The land cover percentages for the 300-m buffer around each stream tributary according to the NHAP data are presented in Figure 3. The percent cover in forest, grassland, or mixed successional varies widely among the 30 tributaries, from 0 to 53%. The average cover percentages for all 30 tributaries and for all six major land covers, within the buffer and over the entire basin, are given in Figure 4 for each of the three data sets.

The NHAP data set used the level III classification shown in Table 2. Over the entire basin, land cover percentages were dominated by agriculture, which occupied a total of 91% of the basin (Figures 3 and 4a). Among streams in the basin, average land cover percentages (and ranges) were: 15.6% forest (0%–43.1%), 1.7% grassland (0%–12.6%), 2.3% mixed successional (0%–11.6%), 77.7% agriculture (45.6%–100%), 1.9% urban (0%–20.4%), and 0.6% water (0%–7.6%).

For the entire TM study area (minus the 8% land not covered by the TM data), the land-cover percentages were similar to that found in the other data sets (Figure 4b). Forest within the stream buffers for the TM data averaged (range) 9.4% (0%–29.3%), 4.7% (0%–19.6%) for grassland, 4.0% (0%–8.9%) for mixed successional, 79.5% (0%–99.9%) for agriculture, 2.1% (0%–20.5%) for urban, and 0.3% (0%–1.1%) for water.

The level II LUDA data did not differentiate any grassland for this region. For the entire basin and thus excluding the possibility of grassland, the percentage of each land cover ranged from 0.1% for mixed successional and water to 2% for forest to 94% for agriculture (Figure 4c). As with the other data sets, there was a wide variation among the 30 tributary buffers, with an average (range) forest of 6.0% (0%–22.5%), 0.2% (0%–5.1%) for mixed successional, 90.5% (75.2%–100%) for agriculture, 2.5% (0%–19.7%) for urban, and 0.3% (0%–3.4%) for water.

Overall, trends for the LUDA, NHAP, and TM data sets show that the percentage of forest, grassland, and mixed successional land cover was higher in the buffer than in the basin as a whole (Figure 4). Not surprisingly, the reverse was true for agricultural and urban areas. The percentage of water was very low but tended to be higher in the buffer as compared to the total basin. The substantially higher proportion of forest, grassland, and mixed successional habitat within 300-m of the streams reflects the importance of riparian zones to wildlife in Illinois and the obvious need to manage these valuable resources. Mounting evidence also shows the value of the riparian vegetation in reducing sedimentation and nutrient loading to the streams (e.g., Osborne and Wiley 1988; Welsch 1991; Castelle et al. 1994; Gilliam 1994; Vought et al. 1994; Lull et al. 1995).

Average forest cover was highest in NHAP (15.6%), followed by TM (9.4%) and then LUDA (6.0%) data (Figure 4). This trend can be attributed to the decreasing resolution of the data, which will fail to capture smaller and smaller forest patches that are common in this highly fragmented landscape. The importance of such small habitat patches to wildlife is, of course, species dependent. The TM data had somewhat higher proportions of grassland and mixed successional land cover than did the NHAP coverages (Figure 4). These differences can be attributed to the manner in which land cover was interpreted and coded as well as differences in resolution.

The Pearson product moment correlation among land cover categories for the three data sets revealed

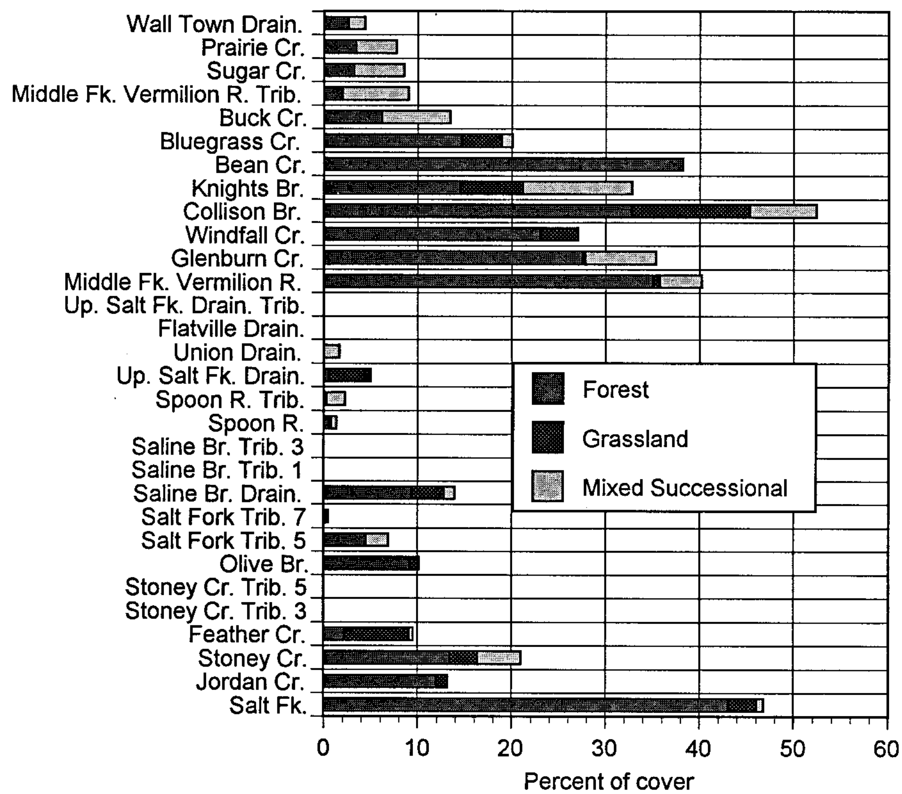

Figure 3. Percentage of forest, grassland, and mixed successional land within the 300-m buffers, by tributary according to the NHAP data. The remaining area is agricultural, urban, or water.

that the percentage of forested, agricultural, and urban land cover types was highly similar for all three data sets ($r > 0.6$, $P < 0.001$, Figure 5). The same was true for the grassland and mixed successional categories in the NHAP and TM data sets (LUDA had no grassland and only two tributaries with mixed successional land, so no correlation values were given). The percentages of water were correlated only for LUDA and NHAP (Figure 5).

Assessment of NWI and NAI data sets. A greater percentage of wetlands, natural areas, and nature preserves are contained within the 300-m buffer of each stream tributary than are contained in the basin as a whole; proportionately four times as many wetlands, three times as much natural area, and two times as much nature preserve are found within the buffer than in the basin. This pattern provides additional evidence that, for the Vermilion River basin, the most valuable sources for high-quality habitat for wildlife are along stream riparian zones. Streams that have the largest percentage of wetlands are the Salt Fork (with 14.7% of its buffer area contained in wetlands), Middle Fork (12.4%), and Windfall Creek (11.3%). Streams that contain the most natural areas are the Middle Fork (1.5% of the buffer area in natural areas), the Saline Branch Drainage Ditch (0.86%), and the Salt Fork (0.75%). Nature preserves are found along only two streams, the Middle Fork (with 5.06% of the buffer in nature preserves) and Windfall Creek (25.79%). Based on these results, streams rating highest for wetlands and high-quality natural areas include the Middle Fork, Salt Fork, and Windfall Creek.

Analysis of Habitat by Tributary

Habitat rating by guild for LUDA, NHAP, and TM data. The habitat ranking scores for LUDA, NHAP, and TM data are presented in Table 4. There is consistency in ranking of the streams with high riparian habitat value across all of the data sets. For instance, the Salt Fork, Middle Fork, Glenburn Creek, and Knights Branch all rank high in forest guild habitat value regardless of the land use data set (Table 4).

The LUDA data ranks the Salt Fork the highest (3.57), followed by Collison Branch (3.31) and the Middle Fork (3.09). The rest of the streams had ratings below 2.8. The grassland guild was not rated due to lack of grassland in the LUDA data. Streams with the highest rating for the mixed successional guild were Collison Branch (2.61) and the Middle Fork (2.41). All other streams had ratings of 2.10 or lower.

With NHAP data, the forest guild rates the Salt Fork at 4.25, Bean Creek at 4.12, and Middle Fork at 4.04

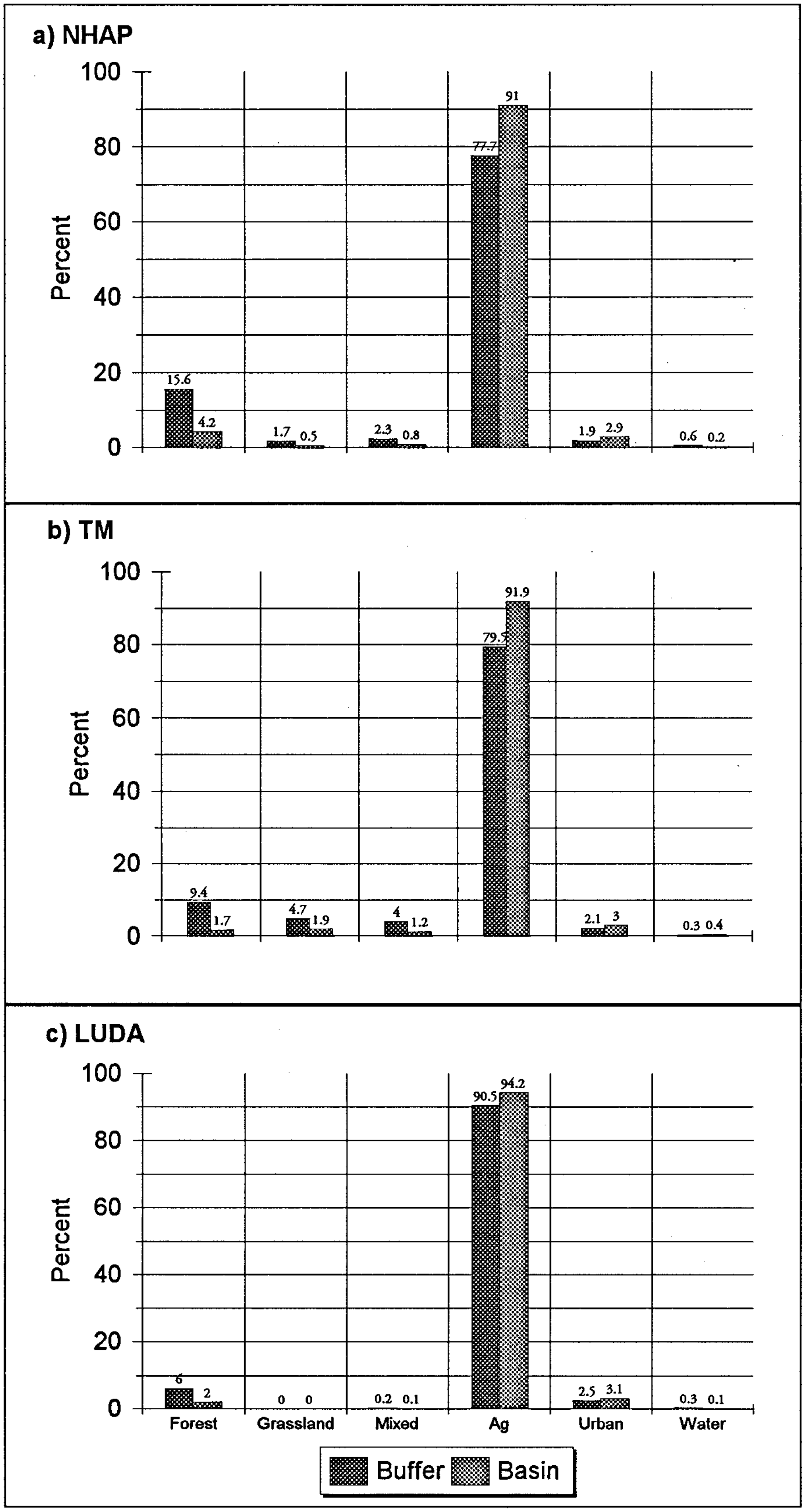

Figure 4. Average percentage of land cover for stream buffers and the entire Vermilion basin, according to the three data sets.

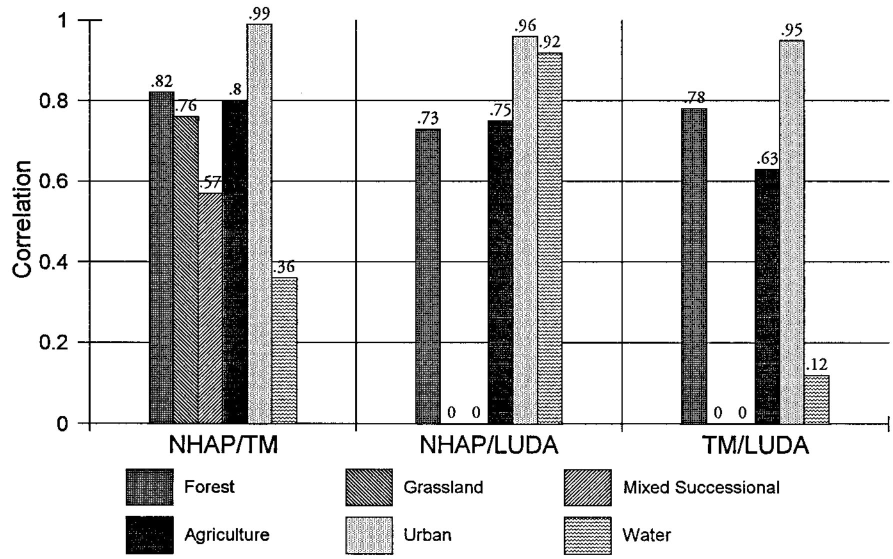

Figure 5. Pearson product moment correlations of percentage of forest, grassland, mixed successional land, agriculture, urban land, and water among three data sources. LUDA data had insufficient grassland or mixed successional data for statistical correlation.

(Table 4). All other streams had ratings below 4. The grassland guild listed Collison Branch with the highest rating (2.98), followed by Feather Creek (2.39) and Knights Branch (2.36). All other streams had ratings below 2. The mixed successional guild rated Knights Branch at 3.56 and Collison Branch at 3.03. All other stream ratings were lower than 3.

The TM data set listed the top-rated stream for the forest guild as Collison Branch (3.85), followed by Bean Creek (3.82), Salt Fork (3.75), and Middle Fork (3.53). All other streams were rated 3 or lower (note, however, that four streams are not represented or only partially represented in the TM data). The top two streams in the grassland guild were Collison Branch (3.43) and Knights Branch (3.31). The other streams were lower than 3. The mixed successional guild rated Knights Branch the highest (3.55), followed by Collison Branch (3.15), and Stoney Creek (3.10). These top three streams match those rated highest for the NHAP data set with respect to habitat for mixed successional species.

Comparison, mapping, and analysis of LUDA, NHAP, and TM data sets. Visual representations of each data set's habitat ratings by guild for each of 30 tributaries were generated from the data in Table 4. An example using TM data for ranking habitat for the forest species is given in Figure 6. For the forest guild, ratings were fairly similar among the three data sets, with NHAP data rating streams slightly higher (Table 4). The Middle Fork, with scores ranging from 3.09 to 4.04, Salt Fork (3.57–4.25), and Collison Branch (3.31–3.96) consistently received the highest values. Many of the remaining streams had much lower ratings. In general, the higher quality forest habitat was restricted to a few streams, usually the larger, high-order streams. There was generally a good correspondence among data sets for their ratings.

Contrary to the habitat ratings for forest species, the grassland habitats tended to be highest on the smaller streams (Table 4). Due to difficulty in the ability of the NHAP data sets to clearly distinguish grassland from mixed successional habitats, streams received generally lower habitat ratings for NHAP compared to the TM data sets. The highest NHAP stream rating was 2.98 for Collison Branch. TM rated Collison Branch, Knights Branch, and the Salt Fork as the highest with ratings of 3.43, 3.31, and 2.77, respectively. LUDA had no grassland identified for the basin, so habitat scores were not generated. Overall, habitat ratings for grassland species in the Vermilion River basin were quite low.

For the mixed successional guild, ratings were varied over the three data sets, with streams generally being rated higher according to the TM data set (Table 4). The LUDA data set rated Collison Branch (2.61) and the Middle Fork (2.41) the highest. Many streams, including the Salt Fork, had zero ratings from LUDA data (which by default equaled 0.15). The NHAP data set rated Knights Branch (3.56) and Collison Branch (3.03) the highest. It also had several streams rated between 2.25 and 3; the Middle Fork was rated 2.52 and the Salt Fork 1.39. Other streams rating fairly high were Collison Branch (3.03), Stoney Creek (2.99), and Bluegrass Creek (3.03). The TM data again rated Knights Branch (3.55), followed by Collison Branch (3.15), as the highest rated streams for mixed successional habi-

Table 4. Habitat rating (0–5 scale) by tributary for LUDA, NHAP, and TM data sets[a]

	Forest			Grassland		Mixed successional		
Tributary	LUDA	NHAP	TM	NHAP	TM	LUDA	NHAP	TM
Salt Fork	3.57	4.25	3.75	1.66	2.77	0.15	1.39	3.09
Jordan Creek	0.15	2.93	3.03	0.98	1.75	0.15	2.34	2.82
Stoney Creek	0.99	3.04	2.73	1.64	1.94	0.65	2.99	3.1
Feather Creek	0.15	1.43	0.96	2.39	2.59	0.15	2.07	2.21
Stoney Creek tributary 3	0.15	0.15	0.15	0.15	0.18	0.15	0.15	0.16
Stoney Creek tributary 5	0.15	0.15	0.15	0.15	0.43	0.15	0.15	0.3
Olive Branch	1.21	2.66	2.28	0.86	1.81	0.81	2.1	2.36
Salt Fork Tributary 5	0.15	2.01	0.9	0.15	1.87	0.15	2.01	2.1
Salt Fork Tributary 7	0.15	0.53	0.4	0.15	0.65	2.10	0.36	0.63
Saline Branch drainage ditch	1.71	2.69	2.49	1.75	1.24	1.46	2.47	2.78
Saline Branch tributary 1	0.15	0.15	0.15	0.15	0.16	0.15	0.15	0.16
Saline Branch tributary 3	0.15	0.15	0.15	0.15	0.17	0.15	0.15	0.16
Spoon River	0.15	0.59	0.48	0.43	0.65	0.15	0.85	0.9
Spoon River tributary	0.15	0.48	0.16	0.15	1.81	0.15	1.34	1.6
Upper Salt Fork drainage ditch	0.15	0.60	0.44	1.98	1.69	0.15	1.5	1.31
Union drainage ditch	0.15	0.15	0.17	0.15	0.98	0.15	1.19	1.09
Flatville drainage ditch	0.15	0.15	0.15	0.15	0.78	0.15	0.15	0.51
Upper Salt Fork drainage ditch tributary	0.15	0.15	0.15	0.15	0.49	0.15	0.15	0.33
Middle Fork	3.09	4.04	3.53[b]	0.72	2.48[b]	2.41	2.03	2.83[b]
Glenburn Creek	2.28	3.78	2.01b	0.41	2.06[b]	1.67	2.48	2.67[b]
Windfall Creek	2.74	3.60	—[b]	1.88	—[b]	2.08	1.33	—[b]
Collison Branch	3.31	3.96	3.85	2.98	3.43	2.61	3.03	3.15
Knights Branch	1.49	3.12	2.92	2.36	3.31	1.02	3.56	3.55
Bean Creek	2.32	4.12	3.82[b]	0.15	2.52[b]	1.70	0.15	2.81[b]
Bluegrass Creek	0.15	3.13	2.57	1.95	2.48	0.15	2.8	3.03
Buck Creek	0.15	2.28	2.17	0.15	2.15	0.15	2.78	2.66
Middle Fork Vermilion River tributary	0.15	1.34	0.67	0.15	2.13	0.15	2.52	2.39
Sugar Creek	0.15	1.72	1.57	0.15	1.18	0.15	2.38	2.37
Praire Creek	0.15	1.76	1.7	0.15	1.3	0.15	2.25	2.21
Wall Town drainage ditch	0.15	1.56	1.53	0.15	1.14	0.15	2.25	2.21

[a]LUDA did not record any grasslands, so no score is given there.

[b]These streams have some TM data missing, which accounts for some of the large discrepancies in habitat ranking.

tats. The Salt Fork rated much higher than in the NHAP data set with a rating of 3.09.

From analysis of these three data sets, it is clear that the streams with the best potential overall wildlife habitat include the Salt Fork, Middle Fork, Collison Branch, Knights Branch, and Bean Creek. It is also evident that successional and grassland land cover categories, as compared to forest, produced wildlife habitat ratings that were more varied and less reliable due to inconsistent classification, inadequate spatial resolution (with LUDA), small areas, and small average patch size.

The habitat rating for the three land cover sources (LUDA, NHAP, and TM) were compared using a Spearman rank correlation test (Figure 7a) and a Pearson product moment correlation test (Figure 7b). Both correlation tests revealed similar results. The forest ratings among the LUDA, NHAP, and TM data sets were all highly correlated. Habitat rankings generated using NHAP and TM data sets were highly correlated for mixed successional species as well, with a lower relationship for the grassland class. All comparisons involving LUDA were lower, due to lower resolution data and due to little or no area in the mixed successional or grassland types. The LUDA data are inadequate for this type of analysis, whereas the TM provides a feasible alternative to the very labor-intensive effort of analyzing high-resolution aerial photographs (as was done with NHAP data).

Conclusions

1. The method presented can successfully produce wildlife habitat rankings by tributary. The three data sets (TM, NHAP, LUDA) compared favorably among each other when analyzed at the stream level for forest habitat. NHAP and TM compared favorably for grassland and mixed successional habitats, but inadequate spatial resolution and classification inconsistency of the LUDA data was respon-

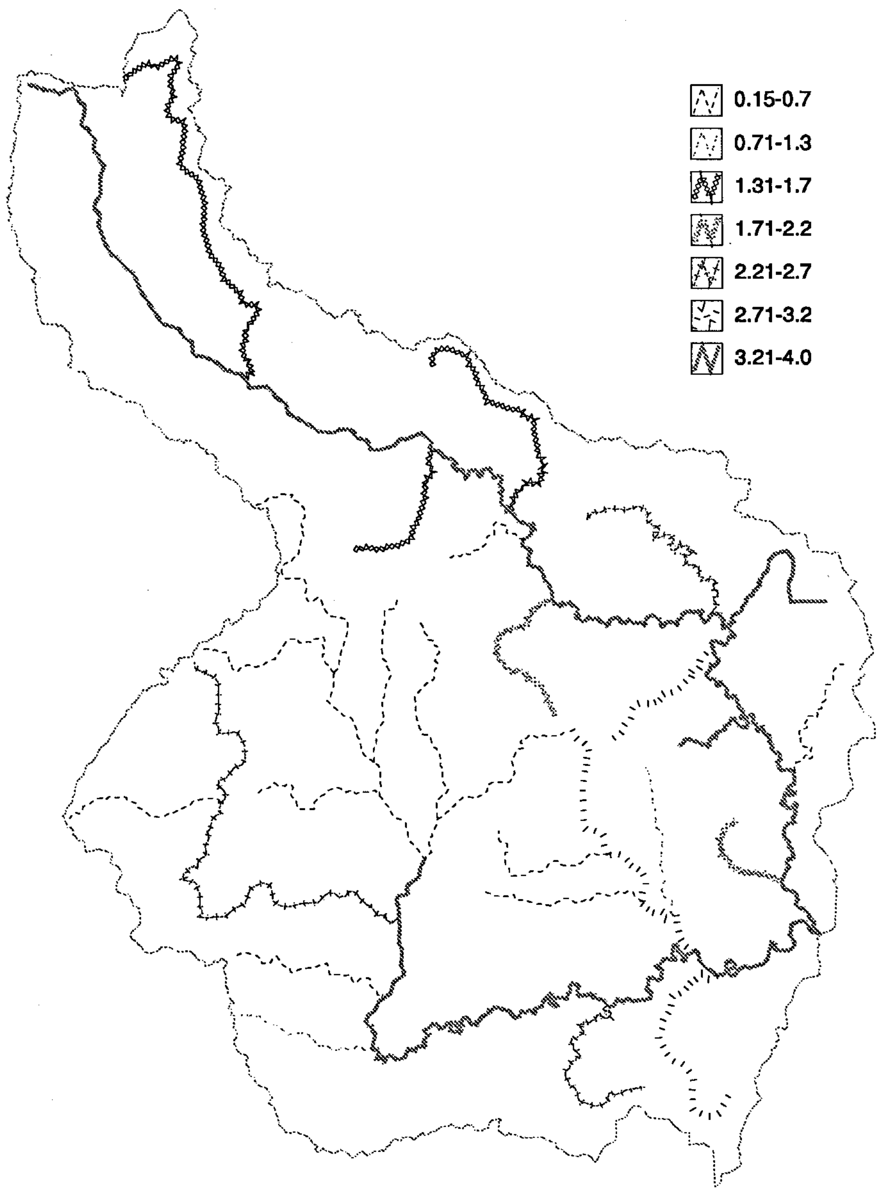

Figure 6. Wildlife habitat ratings mapped for forest species based on TM data.

sible for less than satisfactory results for that data set.

2. The method can inexpensively and consistently be applied to large areas. TM data were shown to provide very good information for this purpose. TM, and other readily available satellite data, once they are classified, can be easily processed for this ranking scheme. Many states are producing TM-based land cover maps for their gap analysis programs (e.g., Scott et al. 1993); these could feed right into this scheme. With suitable GIS hardware and software, adequate land cover data, and a stream network database, the entire process could be performed over an entire state in a matter of a few days. It could also be easily repeated every decade or so for temporal comparisons. Hewitt (1990) also found TM to be useful in inventorying riparian forests. NHAP also provided very good information, but use of those data are not practical on a statewide or larger basis because of the manual interpretation that is involved. Possibly, automated processing on other data, such as digital orthophoto quads or other satellite data may be feasible and warrants further study. LUDA data were acceptable for forest guilds, but the coarser resolution, lack of grassland and mixed successional habitat classes, and one-time date (late 1970s) limit their usefulness in statewide assessments.

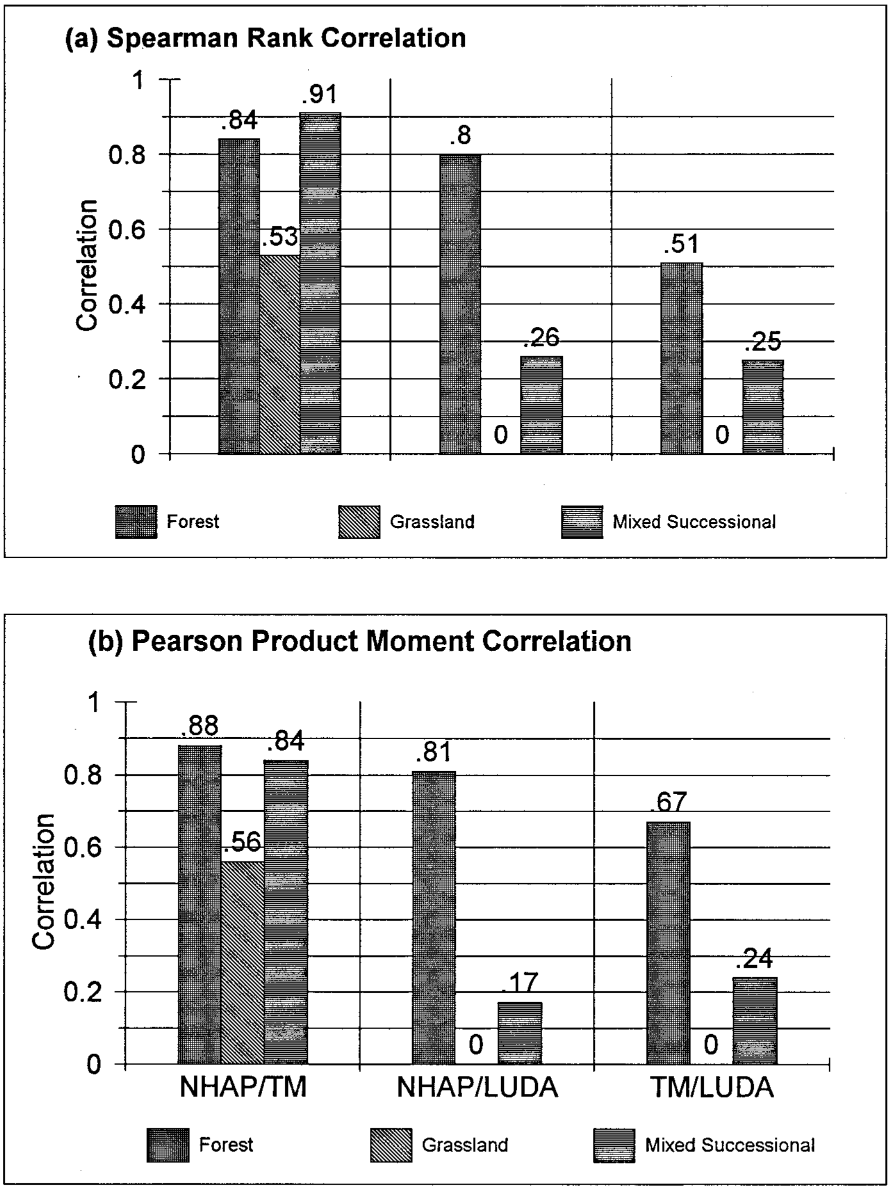

Figure 7. (**a**) Spearman rank and (**b**) Pearson product moment correlations among habitat quality ranks for the three databases. No data existed for LUDA grasslands, resulting in 0.0 correlations.

3. Streams within the Vermilion River basin were rated for habitat value for guilds using forests, grasslands, and mixed successional habitat. In general, for the forest and mixed successional habitat, the larger the stream and the higher the hierarchical order, the better quality of habitats for wildlife. For example, the Salt Fork and Middle Fork rate higher than the tributaries that flow into them. For grassland habitat, the roles are reversed where the smallest tributaries (low in hierarchical order) have the highest habitat rankings.
4. The results of this project provide a sound foundation for rating riparian habitats across large areas. There is a need for continuing research to implement the work on other basins across the country and at a greater level of objective precision, while minimizing effort. In our results we have tried to take into account the many difficulties in rating the value of an area for wildlife habitat and to provide a useful index for managers and other researchers. Nonetheless, it should be remembered that these data and the scoring system are generalized to major wildlife guilds and are based on the best estimates and experiences of the ecologists involved. Optimally, future work would entail field testing and perhaps modification of the method as more

information is obtained and synthesized. The more information available on specific habitat requirements of a target species or guilds, the more accurate a relationship can be developed between the land-cover data and habitat quality.

5. Information presented here from this Illinois study should provide resource managers and policy-makers with a mechanism to identify areas what types of riparian habitats may yet exist and to make preliminary assessments of the quality of the area as wildlife habitat. Such information should be important to the endangered species and heritage programs throughout the country, as well as scientists and land managers interested in monitoring or improving wildlife habitat in their locations.

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