Using Geographic Information Systems to Prepare Sensitive Species Information for Land Use Master Planning

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Abstract

Michigan Natural Features Inventory (MNFI) incorporated its database of rare species and other high quality natural features into data layers for land use planning. These models are designed to incorporate potentially sensitive and difficult to interpret biological information into land use planning efforts while minimizing the sensitive nature of these data.

Three different models are presented here. The first model is a relatively simple frequency count intended to show users where there are concentrations of documented occurrences of rare species or natural communities. The second model is intended to show the likelihood of finding a rare species or other high quality natural feature in any given area. This likelihood model is based on the spatial extent of documented occurrences, the presence of potential habitat within the known extent of the occurrences, and the age of each occurrence. The third model calculates a value for an area of interest that measures the contributions of that area to biodiversity. Like the likelihood model, the biodiversity value model incorporates the spatial extent of documented occurrences, presence of potential habitat within the known extent of the occurrences, and the age of each occurrence. In addition, the biodiversity value model incorporates the species' or natural community's global status, state status, and a quality rank assigned to each occurrence.

The model outputs are Geographic Information System (GIS) layers. This allows the model outputs to be utilized as stand alone data sets or to be incorporated into a GIS based decision support system.

Background

MNFI data

Michigan Natural Features Inventory has been inventorying and tracking Michigan's threatened, endangered, and special concern species and high quality natural communities since 1979. Currently MNFI tracks 417 plant species, 248 animal species, and 74 natural community types. In addition to species and natural communities, MNFI tracks other natural features such as colonial bird nesting colonies and significant geological features. The tracked species include those with Federal and State legal protection and special concern species which have no legal protection. Like the special concern species, the natural communities have no legal protection status. The MNFI database contains over 13,500 records of these natural features. Data sources include museum and herbarium collections, published reports, MNFI field surveys, and information from cooperators. Database records span a range from historic information to very current information from the latest field season.

The MNFI database is a Natural Heritage database and utilizes Natural Heritage methodology and data standards originally designed by The Nature Conservancy and now maintained by Natureserve (www.natureserve.org). The MNFI database is more than a presence/absence database. Among other information, it contains dates of sightings, global and state imperilment rankings for species, and a quality (or viability) ranking for individual occurrences. Definitions of the global and state (or sub-national) rankings can be found in appendix A. The quality ranking is an A – D scale with A being the highest quality. Other codes such as E for extant, H for historic, and X for extirpated are also used. The standards for applying a quality rank to an occurrence vary by species. The MNFI database is continually being updated and is the most complete record of Michigan’s sensitive species and natural features.

Prior to Geographic Information Systems (GIS), each record of a species occurrence was mapped on a USGS 7.5 minute quadrangle map (Figure 1). A sticky dot was placed on the map at the center of the occurrence location and the estimated lat/long recorded in the database. Each record was also assigned a mapping precision based on the known location. Second precision records meant the location was known to within 100 meters. Minute precision records were known to occur within a mile and a half of the lat/long point. General precision records were known only to the township or quadrangle name level.

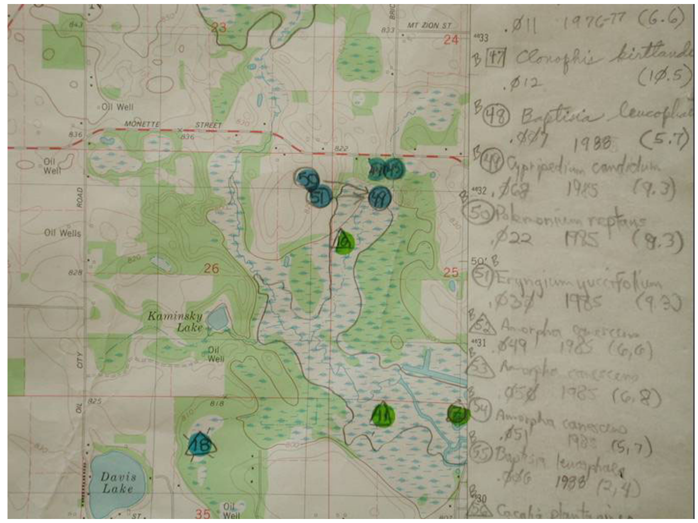

Figure 1: Mapping occurrences on USGS topographic maps.

The MNFI database has now been incorporated into a GIS. The tabular database was given a spatial extent by applying a buffer based on the mapping precision to the estimated lat/long point. Second precision records were given a 100 meter buffer, minute precision records were given a 2,000 meter buffer, and general records were given an 8,000 meter buffer. Newer records are entered as polygons with a digitized spatial extent. Occurrences best represented by a point, (i.e. small plant populations or nest sites) are represented by a small (12 meter) polygon.

The entire MNFI database has been reviewed for spatial accuracy. This process entailed reviewing the original paper records to determine the proper spatial extent for each record. Where appropriate, the spatial extent of each occurrence was changed from a buffered point to an extent supported by the original occurrence report. If the reviewed documentation did not support changing the existing buffer, the existing buffer was kept to define the spatial extent.

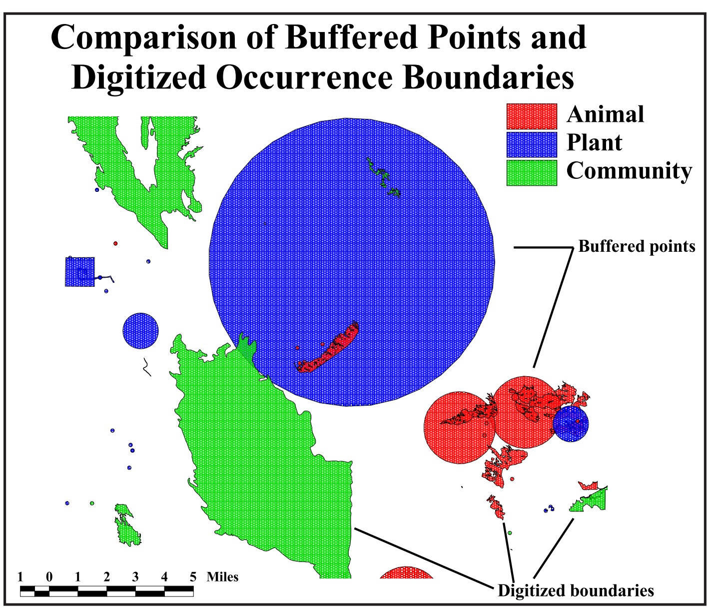

Figure 2: Comparison of buffered points and digitized occurrence boundaries

All re-digitizing was performed to Natural Heritage methodology specifications. Natural Heritage methodology requires that only the described spatial extent of an occurrence be used to represent the occurrence boundary. For example, if a particular occurrence is only reported to be in a particular Public Land Survey System (PLSS) section (~ a square mile) then the section boundary becomes the spatial extent of the occurrence. Figure 2 shows examples of occurrences represented by both buffered points and digitized spatial extents.

Needs

Governmental entities and private citizens wish to include information about rare species and other natural features into their land use planning process. There are, however, various hindrances to utilizing this type of information in land use planning efforts. The MNFI database was designed by Natural Heritage scientists for use by Natural Heritage scientists and other conservation partners. Natural Heritage data was not designed for land use planning. While MNFI data are made available for land use planning, most potential users lack the background and training to properly interpret and employ these data. Historic occurrences in the database present a good example of this problem. One hundred year old plant occurrence records generally mean little for current land use planning efforts. To a Natural Heritage scientist, however, these records are an important indicator of what species assemblages could be encountered within proper habitat in a given area.

Another hindrance is the ambiguous nature of biological information. For example, using a Global Positioning System (GPS) unit, the physical location of a rare animal can be fixed to within a few meters. Animals, however, are mobile creatures. While the observed location of an animal can be easily relocated, there is no guarantee the animal will be present on any given day. This ambiguous nature of species' locations can make it difficult for someone not trained in the proper use of biological information to properly interpret the information.

The single largest obstacle to incorporating MNFI data into land use planning is data sensitivity. Two particular issues, species sensitivity and private property, are central to the requirement to treat MNFI data as sensitive information. The MNFI database contains some very specific locations of rare species, including species that are subject to collection or persecution. In addition, some occurrences in the database are located on private property. Indiscriminate distribution of MNFI data could lead to accidental or deliberate harm to the species or affect perceived private property values. In several instances, private property owners have informed MNFI about species on their property but requested that MNFI not incorporate the data into the database.

MNFI data should be used to protect at risk species. The sensitive nature of these data, however, limits their wholesale distribution to the public. This in turn limits the usefulness of the data for protecting rare and sensitive species. Land use master planning provides an excellent example of this conundrum. Using MNFI data to influence land use decisions can lead to greater species protection. Use of specific location information in a public master planning process can, however, highlight potentially sensitive species locations or private property containing sensitive species.

Certain types of projects or developments are reviewed by the Michigan Department of Natural Resources (MDNR) for potential impacts to rare species. The MDNR annually processes approximately 3,500 project reviews and each review takes approximately one month to process. The MNFI database is the primary data source used for these reviews. The conclusion in approximately 80% of these reviews is no impact to sensitive species. This high no impact rate, coupled with the long processing time, suggests that this review process is not the most efficient way of insuring sensitive species protection. Also, this review process is reactive in nature, usually occurring after a project is proposed or underway.

A more proactive and efficient way to achieve species protection is to incorporate a form of MNFI data early in the land use master planning process. This proactive use of the data can help identify those areas most appropriate for development or those areas deserving of protection. The issue is to provide MNFI data in a manner useful for land use master planning while minimizing the sensitive nature of the data.

Model descriptions

Three different models, a frequency count, a probability or likelihood model, and a biodiversity value model, are presented here. The models are presented at three different resolutions based on the political boundaries of the Public Land Survey System. The three resolutions are the PLSS section (~ 1 $mile^2$ or 640 acres), quarter section (~160 acres), and quarter-quarter sections (~ 40 acres). While the models could be completed using any appropriate boundaries, political or ecological, the PLSS system provides a well recognized analysis framework. Also, aggregating up to a minimum mapping unit of 40 acres serves to mask very precise species locations. The model outputs are in a GIS format so they can be utilized independently or incorporated into a GIS based Decision Support System (DSS).

The frequency count is a simple count of the number of occurrences within any given area of interest. All the natural features polygons that overlap into the area of interest are counted for that area. The frequency count is intended to show users where there are concentrations of occurrences. Maps of the frequency counts are available on a county by county basis from the MNFI web site (www.msue.msu.edu\mnfi).

The probability model is intended to show the likelihood of finding a rare species or natural community in any given area. Despite its name, the model is not probabilistic in the sense that it provides a statistical probability of an occurrence. The underlying assumption is that the more recent an occurrence has been observed, the more likely it is to still exist. Factors considered in the model are the spatial extent of the occurrences, the presence of potential habitat within the known spatial extent of the occurrence, and the last observed date of the occurrence. The use of appropriate habitat within the known extent of an occurrence is used to effectively change the known spatial extent of the occurrence. The age of each record is then used to determine the likelihood of the species still being present, with recent sightings given a higher likelihood of still existing.

In this particular application of the model, records prior to 1970 are given a low probability of still existing. Records after 1982 are given a high likelihood of still existing. By default records between 1970 and 1982 are given a moderate probability of still existing. No distinction is made between animal or plant occurrences. Also, a higher probability supercedes a lower probability. For instance, if an area of interest contains two occurrences with low probability and one occurrence with high probability the area is assigned a high probability.

The biodiversity value model is designed to help prioritize areas for conservation by scoring areas of interest for their contributions to biodiversity. It does this by calculating a biodiversity value for each occurrence within an area then summing the values of all the occurrences within the area. Factors considered in calculating the biodiversity value of each occurrence include the species' global status, state status (or subnational status), the quality rank assigned to each occurrence, and the last observed date of the occurrence. Like the probability model, the biodiversity value model also utilizes the presence of potential habitat within the known spatial extent of the occurrence. The biodiversity value is an open ended scale with zero representing no known occurrences or no appropriate habitat within the area.

Models have been produced for 13 Michigan counties; Alger, Chippewa, Delta, Ingham, Jackson, Luce, Mackinac, Macomb, Marquette, Oakland, Schoolcraft, St. Clair, and Wayne. These counties represent geographically and ecologically diverse areas of the state.

Methodology

Frequency count

The frequency count is a count of all occurrences that fall within a given PLSS section. The model utilizes a statewide GIS data layer (Environmental Systems Research Institution (ESRI) shapefile) of the PLSS sections. A numeric count field is added to the section shapefile theme table. Each section shape is selected in turn and intersected with the MNFI GIS database. The number of occurrences intersecting each section shape is counted and that value is calculated into the count field in the section shapefile theme table.

The frequency count is created utilizing a script in ESRI ArcView 3.X. The model is completed at the PLSS section level resolution on a statewide basis. Large file size limits the practicality of utilizing a finer resolution on a statewide basis. The model could be created at a finer resolution (e.g. quarter section or quarter-quarter section) over a smaller geographic extent.

Likelihood model and biodiversity value model

The overall modeling process consists of grouping species into habitat guilds, creating a habitat layer for each guild, using the habitat layer to redefine the spatial extent of the appropriate occurrences, intersecting the spatially redefined occurrences with political boundaries (PLSS unit) then assigning each political unit a probability value and a biodiversity value.

The process starts by grouping species into habitat classes and a assigning a habitat identifier code to each species occurrence. Features in the MNFI database such as geological formations are removed from the analysis. The next step is to create a habitat layer for each habitat class. For Jackson County, habit layers for each class were extracted from the 1978 Michigan Resource Information System (MIRIS) land use coverage dataset, the National Wetlands Inventory dataset, and the National Hydrological Dataset. All other models utilized the 2000 Integrated Forest Management, Assessment and Prescription (IFMAP) land cover dataset for terrestrial habitats.

The habitat layers are then used to redefine the spatial extent of the occurrences. This is accomplished by selecting all the occurrences with a given habitat code then clipping the selected occurrences using the appropriate habitat layer as the clipping overlay theme. The result of this operation produces a new theme for each habitat group. In each new theme the spatial extent of each occurrence is replaced by the spatial extent of the habitat within the original boundary of the occurrence (Figure 3). The new theme retains all the database attributes of the original occurrence database. Where fragmented habitat patches occur within an occurrence boundary, the occurrence will be converted from a single shape to a multiple shapes. The clipping operation was not performed on natural community occurrences because the communities have a defined spatial extent. The natural communities are selected out of the occurrence database and converted to a separate layer.

The themes for each habitat group and the natural community themes are then all merged together. After merging the themes for each habitat type into a single theme, the merged theme is dissolved on the unique code number assigned to each individual occurrence. This operation consolidates all the separate shapes for each occurrence into a single shape. Each occurrence is then assigned a value based on the age of the record. This value is used to represent the likelihood of the occurrence still existing. Occurrences with a last observed date of no later than1982 are assigned a value of one, occurrences between 1970 and 1982 are assigned a value of 0.5, and occurrences prior to 1972 are assigned a value of 0.25. All natural community records are assigned a value of one.

Each occurrence is also assigned three other values, one based on the species global status, one based on the species state status, and one based on the occurrence quality rank. The greater the threat of imperilment to the species, the higher the value assigned to the occurrence. In a similar manner, the higher the quality of each occurrence, the higher the value assigned to it (Table 1). The biodiversity value of each occurrence is then calculated by adding the values for the global status, state status, and the quality ranking, then multiplying the sum by the age based value.

To create the probability value for the PLSS data set, all records in the PLSS data set are selected and assigned a “No Status” value. Next the records in the species database with the lowest probability of still existing (value = 0.25) are selected. The PLSS data set is intersected with the species database and the selected PLSS records are assigned a value of “Low.” Next those records with a moderate likelihood of still

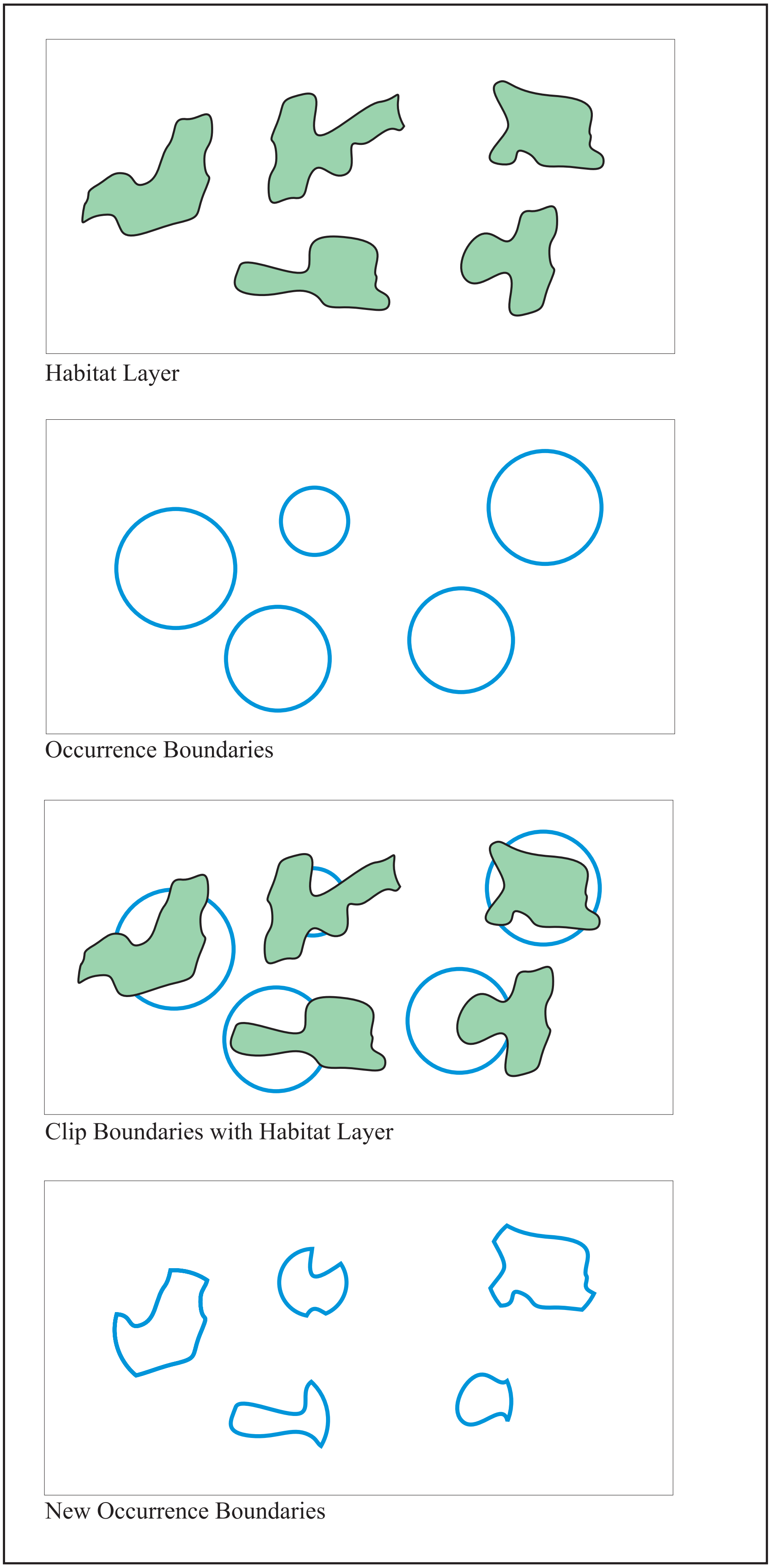

Figure 3: Replacing occurrence boundaries with habitat boundaries

Table 1: Values assigned for species' global, state, and element occurrence ranks

Values Assigned for Specie's Global and State Ranks and Element Occurrence Ranks					
Global Rank	**Score**	**State Rank**	**Score**	**Occurrence Rank**	**Score**
G1	10	S1	5	A	5
G2	6	S2	4	B	4
G3	3.5	S3	3	C	3
G4	2	S4	2	D	2
G5	1	S5	1	E	1
U	1	SU	1	F	1
				U	2
				X	0
				H	0
				No Rank	2

existing are selected (value = 0.5). The PLSS data set is intersected with the species database and the selected PLSS records are assigned a value of "Moderate." Finally the records in the species database with the highest probability of still existing (value = 1) are selected. The PLSS data set is intersected with the species database and the selected PLSS records are assigned a value of "High." Performing the selections and intersections in this order insures that a higher probability in any PLSS feature will override a lower probability.

To calculate the biodiversity value of a given PLSS feature, each feature in the PLSS theme is selected in sequence. Next, all the species occurrences intersecting the PLSS feature are selected. Then the biodiversity values of the selected species occurrences are summed and assigned to the PLSS feature. The result is a value for each PLSS unit that is the sum of the biodiversity values of all occurrences falling within the PLSS unit.

Results

Frequency count

Table 2 shows the results of the frequency count at the PLSS section resolution from a count performed in August of 2004. For convenience, the counts are grouped into five count increments. Table 2 also shows the percentage of the county in each five point increment. In the zero occurrences per section category, Luce County had the highest percentage of a county with no occurrences (72.84%) while Oakland had the lowest percentage (3.78%). In the greater than 15 occurrences per section category, St. Clair County had the highest

Table 2: Number of element occurrences per PLSS section in five point increments

Number of Element Occurences per PLSS Section In Five Point Increments August 2004										
	0		**1 - 5**		**6 - 10**		**11 - 15**		**> 15**	
	Number	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**
Alger	658	64.89%	339	33.43%	14	1.38%	2	0.20%	1	0.10%
Chippewa	832	45.61%	946	51.86%	38	2.08%	8	0.44%	0	0.00%
Delta	895	69.81%	368	28.71%	19	1.48%	0	0.00%	0	0.00%
Ingham	182	31.87%	306	53.59%	43	7.53%	36	6.30%	4	0.70%
Jackson	301	41.81%	382	53.06%	34	4.72%	2	0.28%	1	0.14%
Luce	692	72.84%	258	27.16%	0	0.00%	0	0.00%	0	0.00%
Mackinac	554	45.45%	566	46.43%	93	7.63%	5	0.41%	1	0.08%
Macomb	256	52.57%	181	37.17%	28	5.75%	22	4.52%	0	0.00%
Marquette	1017	52.67%	860	44.54%	51	2.64%	3	0.16%	0	0.00%
Oakland	34	3.78%	716	79.56%	134	14.89%	15	1.67%	1	0.11%
Schoolcraft	622	49.76%	607	48.56%	20	1.60%	1	0.08%	0	0.00%
St. Clair	348	44.79%	284	36.55%	73	9.40%	54	6.95%	18	2.32%
Wayne	154	23.51%	430	65.65%	48	7.33%	15	2.29%	8	1.22%

percentage of the county (2.32%). Four counties, Chippewa, Delta, Luce, and Schoolcraft, had no sections in the greater than 15 occurrences per section category.

Table 3 shows the high counts for each county. High counts ranged from a low of five in Luce County to a high of 34 in Ingham County.

Table 3: Highest number of element occurrences in a PLSS section

Highest Number of Element Occurrences in a PLSS Section	
Alger	16
Chippewa	14
Delta	10
Ingham	34
Jackson	20
Luce	5
Mackinac	16
Macomb	14
Marquette	15
Oakland	16
Schoolcraft	11
St. Clair	30
Wayne	25

Probability model

Table 4 shows the percentages of each County in any given probability class for each of the three model resolutions (PLSS section, quarter section, and quarter-quarter section). At the section level, the percentages of the county in the high probability category ranged from a high of 40.1% for Mackinac County to a low of 5.5% for Wayne County. At the quarter-quarter section resolution the percentages of the county in the high probability category dropped to 16.7% for Mackinac County and 2.4% of Wayne County.

In the no status category, percentages at the section level ranged from 66.1% for Alger County down to 4.0 % for Oakland County. At the quarter-quarter section resolution, the percentages of the county in the no status category increased to 84.1% for Alger County and 11.8% for Oakland County.

Biodiversity values model

For convenience, the biodiversity value scores are grouped into ranges of zero, 0.1 – 10. 10.1 – 20, 20.1 – 30, 30.1 – 40 and greater than 40. Table 5 shows the percentages of each County in any given classification for each of the three model resolutions. Figure 4 is a graph of the percentage of each county in the ten point range groupings at the quarter-quarter section resolution.

Mackinac County had the highest percentage of the county in the over 40 point category (6.8%) at the section resolution while Luce County had no sections in the over 40 points category. At the quarter-quarter section resolution, the percentage of Mackinac County in the over 40 category drops to 0.84 percent.

Table 6 shows the highest biodiversity value score for each county. At the section level, the high scores ranged from a value of 195.75 for Ingham County to 50.75 for Macomb County. When using the finer quarter-quarter section resolution, the high scores ranged from 124.0 for Mackinac County to 33.0 for Luce County.

Discussion

F***requency count***

The frequency count is a relatively simple representation of the MNFI data. It is designed to show users where there are concentrations of known species or natural community occurrences in the MNFI database. While the frequency count provides limited information, it does fulfill its intended purpose. Users can see if there are known occurrences in the vicinity of a proposed project or delineate those areas where there are concentrations of occurrences. All species information is removed so locations of particularly sensitive species cannot be determined from the model.

The advantage of the frequency count is that it is easy to produce. The process is automated and produces a statewide dataset. The statewide dataset can be parsed to whatever political jurisdiction wishes to utilize the

Table 4: The percentages of a county in each probability category by PLSS unit

Percentages of counties in each probability category by PLSS unit												
	Section				Quarter Section				Quarter-quarter Section			
	High	Moderate	Low	No Status	High	Moderate	Low	No Status	High	Moderate	Low	No Status
Alger	27.1%	1.6%	5.2%	66.1%	15.9%	1.1%	5.1%	77.8%	10.4%	0.7%	4.8%	84.1%
Chippewa	28.4%	6.6%	8.4%	56.6%	16.7%	6.6%	7.4%	69.3%	11.3%	6.5%	6.1%	76.1%
Delta	25.2%	6.2%	6.0%	62.6%	14.1%	4.2%	4.6%	77.1%	9.3%	2.6%	3.2%	84.8%
Ingham	11.4%	20.8%	22.4%	45.3%	7.0%	18.2%	25.5%	49.4%	4.2%	13.7%	26.3%	55.8%
Jackson	18.1%	4.0%	30.3%	47.6%	11.1%	2.4%	24.9%	61.6%	7.3%	1.6%	18.6%	72.6%
Luce	20.9%	3.6%	2.0%	73.5%	12.7%	2.2%	1.6%	83.4%	8.9%	1.4%	1.3%	88.4%
Mackinac	40.1%	2.9%	4.1%	52.9%	23.8%	2.1%	3.3%	70.9%	16.7%	1.6%	2.7%	79.0%
Macomb	5.5%	6.6%	32.4%	55.4%	3.5%	3.3%	31.2%	62.1%	2.4%	2.0%	29.6%	66.0%
Marquette	12.3%	1.8%	22.5%	63.3%	6.5%	2.0%	21.0%	70.5%	4.0%	2.0%	19.1%	74.8%
Oakland	26.9%	1.9%	67.2%	4.0%	18.4%	1.5%	72.1%	7.9%	14.5%	1.2%	72.5%	11.8%
Schoolcraft	30.9%	7.4%	10.4%	51.4%	19.1%	6.1%	9.9%	64.9%	12.9%	5.3%	9.1%	72.7%
St. Clair	14.3%	2.1%	37.5%	46.2%	9.5%	1.4%	36.9%	52.2%	6.7%	0.9%	34.0%	58.3%
Wayne	13.9%	4.4%	56.3%	25.3%	7.2%	2.9%	56.4%	33.4%	4.2%	2.7%	53.2%	39.9%

Table 5: Percentage of a county in ten point biodiversity value categories by PLSS unit

Percentage of the county in biodiversity value categories by PLSS unit												
	Oakland			Schoolcraft			St Clair			Wayne		
Biodiversity value	Section	Quarter Section	Quarter-quarter Section	Section	Quarter Section	Quarter-quarter Section	Section	Quarter Section	Quarter-quarter Section	Section	Quarter Section	Quarter-quarter Section
0	4.00%	7.94%	11.77%	51.36%	64.94%	72.65%	46.20%	52.22%	58.32%	25.34%	33.44%	39.95%
0.1 - 10	67.44%	72.42%	72.27%	30.24%	25.15%	21.03%	34.36%	34.29%	32.20%	59.08%	57.93%	54.70%
10.1 - 20	18.56%	14.97%	13.26%	12.96%	7.90%	5.41%	10.30%	8.40%	6.73%	7.33%	4.96%	3.58%
20.1 - 30	4.00%	2.64%	1.83%	2.24%	0.98%	0.55%	4.50%	2.83%	1.78%	3.66%	1.80%	0.94%
30.1 - 40	2.11%	0.86%	0.48%	1.68%	0.59%	0.20%	1.29%	1.13%	0.55%	1.07%	0.66%	0.40%
> 40	3.89%	1.17%	0.38%	1.52%	0.45%	0.16%	3.35%	1.13%	0.41%	3.51%	1.21%	0.44%

Table 5, cont.: Percentage of a county in ten point biodiversity value categories by PLSS unit

Percentage of the county in biodiversity value categories by PLSS unit									
	Alger			Chippewa			Delta		
Biodiversity value	Section	Quarter Section	Quarter-quarter Section	Section	Quarter Section	Quarter-quarter Section	Section	Quarter Section	Quarter-quarter Section
0	66.07%	77.84%	84.13%	56.63%	69.31%	76.12%	51.36%	77.06%	84.79%
0.1 - 10	20.91%	16.37%	12.68%	27.25%	22.03%	18.61%	30.24%	16.03%	10.84%
10.1 - 20	7.69%	3.62%	2.16%	8.72%	5.90%	3.94%	12.96%	5.13%	3.59%
20.1 - 30	3.16%	1.25%	0.63%	3.34%	1.17%	0.64%	2.24%	0.93%	0.51%
30.1 - 40	0.79%	0.45%	0.23%	1.81%	0.65%	0.30%	1.68%	0.44%	0.16%
> 40	1.38%	0.47%	0.18%	2.25%	0.93%	0.40%	1.52%	0.40%	0.11%

Table 5, cont.: Percentage of a county in ten point biodiversity value categories by PLSS unit

Percentage of the county in biodiversity value categories by PLSS unit									
	Ingham			Jackson			Luce		
Biodiversity value	Section	Quarter Section	Quarter-quarter Section	Section	Quarter Section	Quarter-quarter Section	Section	Quarter Section	Quarter-quarter Section
0	45.30%	49.35%	55.85%	47.64%	61.63%	72.55%	73.47%	83.40%	88.39%
0.1 - 10	38.09%	37.16%	33.60%	40.14%	31.49%	23.40%	18.63%	13.41%	10.15%
10.1 - 20	8.78%	9.20%	8.19%	6.25%	4.24%	2.65%	5.16%	2.26%	1.12%
20.1 - 30	5.17%	3.71%	2.08%	2.50%	0.94%	0.41%	2.21%	0.82%	0.33%
30.1 - 40	1.88%	0.40%	0.18%	1.81%	1.18%	0.77%	0.53%	0.11%	0.01%
> 40	0.78%	0.18%	0.10%	1.67%	0.52%	0.22%	0.00%	0.00%	0.00%

Table 5, cont.: Percentage of a county in ten point biodiversity value categories by PLSS unit

Percentage of the county in biodiversity value categories by PLSS unit									
	Mackinac			Macomb			Marquette		
Biodiversity value	Section	Quarter Section	Quarter-quarter Section	Section	Quarter Section	Quarter-quarter Section	Section	Quarter Section	Quarter-quarter Section
0	52.91%	70.89%	75.96%	55.44%	62.07%	66.02%	63.34%	70.53%	74.83%
0.1 - 10	17.39%	14.13%	11.22%	34.29%	30.38%	27.61%	29.67%	25.72%	22.83%
10.1 - 20	12.96%	7.98%	5.65%	5.95%	5.40%	5.15%	4.76%	2.92%	2.00%
20.1 - 30	6.64%	2.98%	5.65%	3.49%	1.89%	1.10%	1.19%	0.52%	0.23%
30.1 - 40	3.28%	1.58%	0.67%	0.21%	0.21%	0.11%	0.78%	0.28%	0.11%
> 40	6.81%	2.43%	0.84%	0.62%	0.05%	0.01%	0.26%	0.03%	0.003%

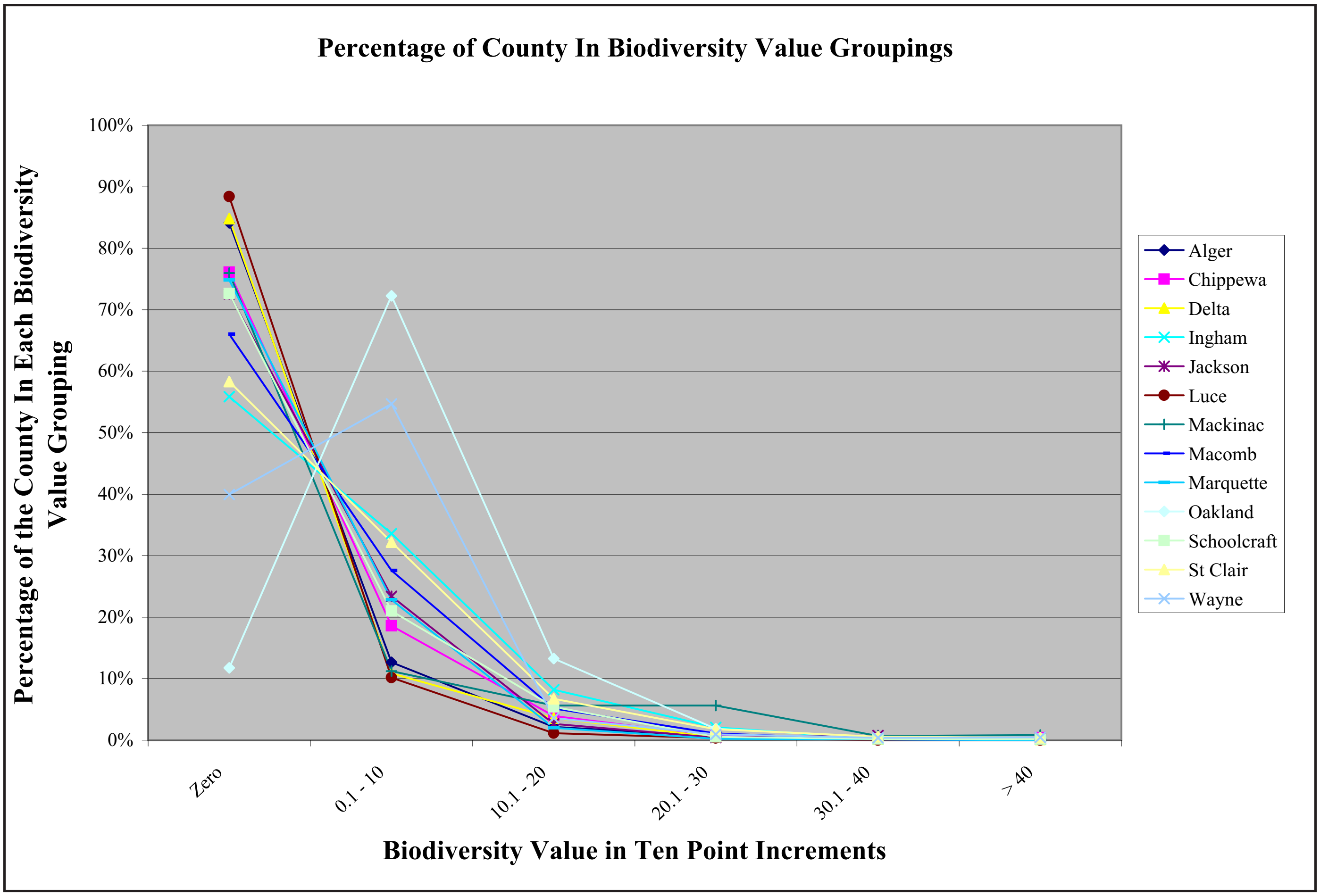

Figure 4: Percentage of a county in each biodiversity value ten point group.

Table 6: Highest biodiversity values at the section, quarter section, and quarter-quarter section resolutions

Highest biodiversity values at the section, quarter section, and quaretr-quarter section levels			
	Section	Quarter Section	Quarter-quarter Section
Alger	114.63	100.13	90.00
Chippewa	130.00	113.00	102.50
Delta	99.50	73.50	73.50
Ingham	195.75	144.75	84.00
Jackson	152.00	148.50	123.00
Luce	38.00	38.00	33.00
Mackinac	150.88	137.00	124.00
Macomb	50.75	40.75	40.75
Marquette	53.50	43.50	43.00
Oakland	110.75	101.25	90.50
Schoolcraft	99.50	99.50	73.00
St. Clair	172.50	117.50	100.50
Wayne	168.38	161.38	121.00

information. As the MNFI database changes, the model can be rerun and the information distributed. While the statewide model produces a frequency count at the PLSS section level, the model can be used at a finer resolution over a smaller geographic area as required.

There are two disadvantages of the frequency count. First, the count utilizes all occurrences in the MNFI database. This includes non-biotic occurrences such as unique geologic features and historic records of species that are likely locally extirpated. The second disadvantage is that it provides the very limited information. The user only knows that the known boundary of an occurrence overlaps the boundary of the area of interest. No allowance is made for the age of the record, relative importance of the species, or the extent of potential habitat within the occurrence boundary.

Probability model
The model is designed to help protect biodiversity and minimize potential regulatory problems by directing development away from those areas with a high likelihood of encountering a sensitive species. Because no specific species information is presented, the model reduces the sensitivity of the underlying MNFI data.

A high probability indicates that the area of interest contains the spatial extent of an occurrence, there is potential habitat within the area, and the occurrence has been observed in the recent past. A low probability indicates that the area contains the spatial extent of an historic species occurrence and there is potential habitat within the area. While the low probability indicates that the underlying occurrences are historic, there is still a possibility that the species persists in appropriate habitat. In the recent past, MNFI botanists have reconfirmed three 100 year old plant records. A moderate probability indicates, by default, something between the other two probabilities.

The probability model provides users with a higher level of information than the simple frequency count. Unlike the frequency count, which only implies that the extent of an occurrence lies within an area of interest, the probability model delineates those areas where there is a higher likelihood of encountering a sensitive species or natural community. Also, by utilizing potential habitat within the known extent of the occurrences, areas without potential habitat are eliminated from consideration.

The probability model can be used in the context of both land use planning efforts and conservation planning efforts. By delineating areas with high likelihood of encountering sensitive species or natural communities, the model can be used to direct development away from those areas. It can also be used to show the areas that are worthy of conservation efforts.

While the probability model can be utilized in conservation planning, it has some shortcomings. A shortcoming of the probability model for conservation planning is that all high probability areas are treated the same. Whether there is one recent occurrence in the area or thirty recent occurrences, the same high probability value is assigned to the area. Nor is there any allowance for the relative imperilment of the species found in any unit of interest. There is no numeric value assigned to any of the units of interest that allow them to be judged relative to each other. Funding constraints usually require prioritization of where funding is spent for conservation. This implies the need to make value judgments of an area in relation to other areas.

Biodiversity value
Unlike the probability model, the biodiversity value model allows similar areas to be compared to each other to determine their relative contributions to biodiversity. Because resources for conservation are generally limited, the biodiversity value model can help direct limited resources to those areas where the resources will have the greatest impact.

Figures 5 through 10 show the differences between the probability model and the biodiversity value model for Jackson County. At the PLSS section resolution, 130 sections out of a total of 720 sections (18%) have a high probability of an occurrence. Only 12 sections have a biodiversity value of greater than 40 (1.6%). At the quarter section resolution, 319 out of 2,880 quarter sections (11%) had a high probability while only 15 (0.5%) had a biodiversity value over 40. At the quarter-quarter section level 840 of 11,472 (7%) had high probability of an occurrence while only 25 (0.2%) had a biodiversity value greater than 40.

To put the biodiversity value scores in context, a single post 1982 occurrence of a species with a G1 global rank, a S1 sub-national rank, and an A occurrence rank, will produce a biodiversity value score of 20. An occurrence with an A occurrence rank, a G2 global rank, and a S1 sub-national rank will produce a score of 16. Of the 695 species and communities that MNFI tracks, only 18 have a G1 global rank and a S1 sub-national rank. A total of 15 species or communities have a G2 global rank and a S1 sub-national rank and 18 species or communities have a G2 global rank and a S2 sub-national rank. Much more typical are G5 species with a State rank of S1 – S4. An historic occurrence of a G5 – S1 species with an E (extant) quality rank will produce a biodiversity score of 1.75.

Out of over 13,500 occurrences in the MNFI database, there are only 231 occurrences of G1-S1 species or communities. This represents less than 2% of the MNFI database. There are 557 occurrences of G2 species or communities representing 4% of the total occurrences.

The small number of G1 and G2 ranked species occurrences, coupled with the penalty placed on older occurrences, serves to minimize the number of areas with a high biodiversity value score. Of the 13 counties modeled here, only Mackinac County had greater than three percent of the county with a biodiversity value greater than 20 at the quarter-quarter section level. Only Mackinac County had greater than one percent of the county with a biodiversity value greater than 30. The low proportion of occurrences that can by themselves produce a biodiversity value of 20 indicates that scores over 20 generally represent a concentration of occurrences.

Data sensitivity/Model resolution

The reason to create these models is to produce information for land use planning or conservation while reducing the sensitivity of the underlying species database. Again, the need to treat the data as sensitive is because of the potential for harm to endangered species and to minimize potential private property issues. All three models do help reduce the sensitive nature of the data while providing useful information.

The frequency count is simply a count of known occurrences within an area. No biological information is presented, other than the potential presence of at least one of the over 600 natural features MNFI tracks.

The probability model indicates the likelihood of an occurrence in any given area but again, no specific species information is presented. The user does not know what species is present or how many species may be present. Each area of interest is given only one probability value and highly sensitive species are treated the same as less sensitive species.

The biodiversity value model goes further than the other models in highlighting areas of biological interest. No specific species information is presented but, the higher the biodiversity value the greater the biological interest. Any given biodiversity value could be attributed to the presence of a highly sensitive species, or higher numbers of less sensitive species, or some combination of both very sensitive and less sensitive species. The higher the biodiversity value, however, the more likely there are more sensitive species present.

The models presented here utilize the PLSS boundaries (sections, quarter sections, and quarter-quarter section) as areas of interest. In theory the models will work for any type of units, however, for land use

Probability of Encountering a Protected Species, Special Concern Species, or High Quality Natural Community at the PLSS Section Level In Jackson County, MI.

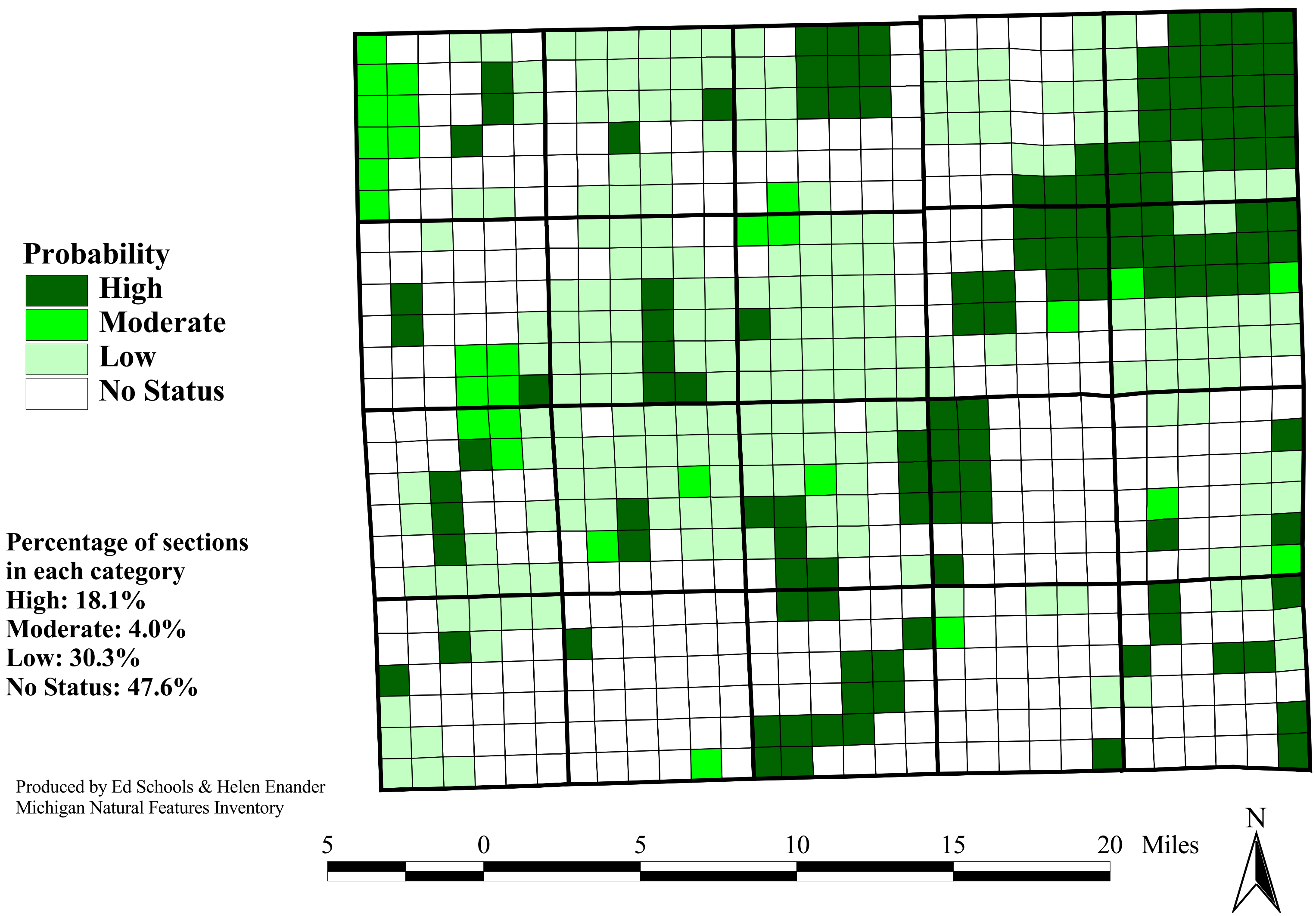

Figure 5: Probability values in Jackson County at the PLSS section resolution

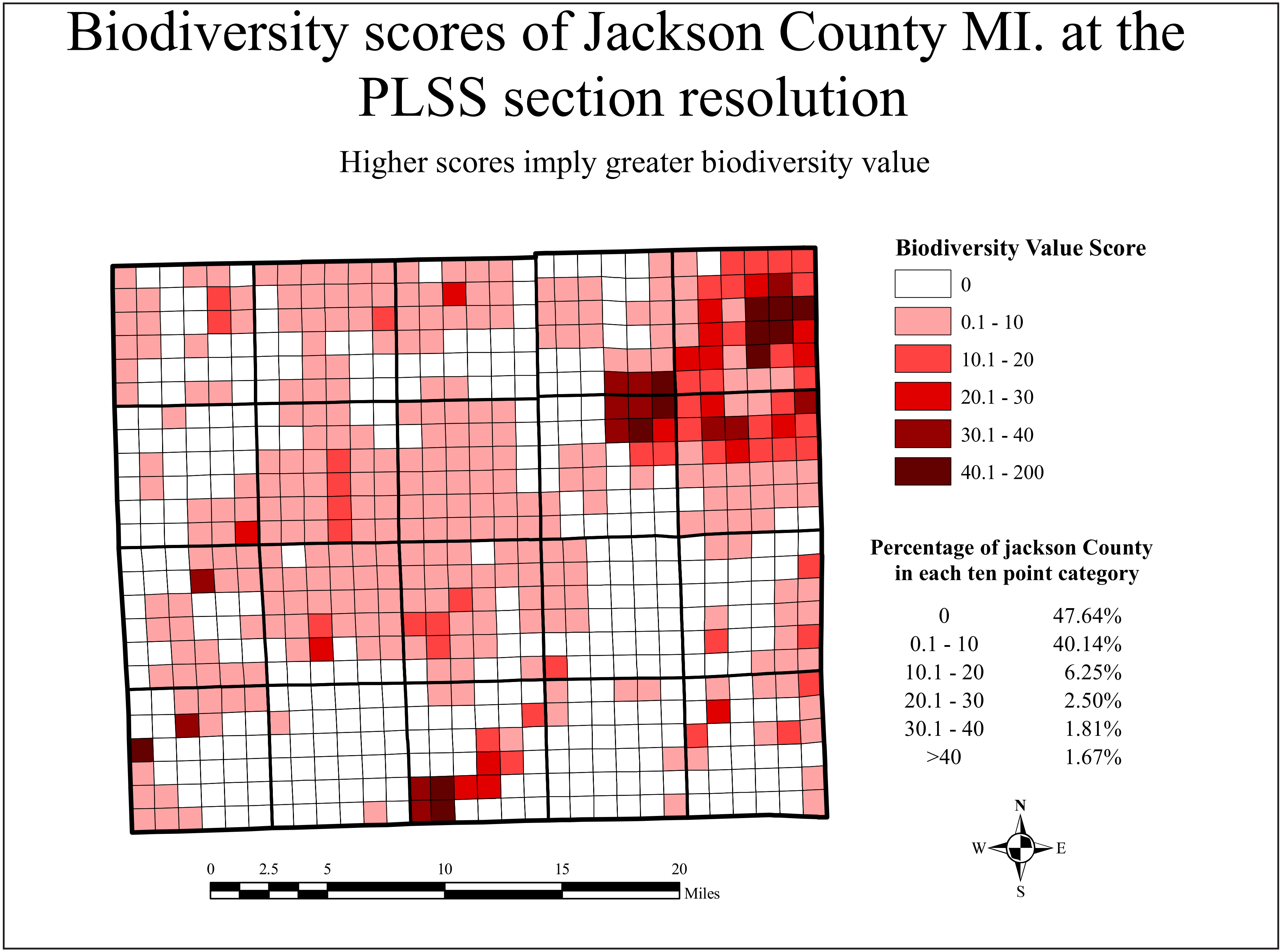

Figure 6: Biodiversity values in Jackson County at the PLSS section resolution

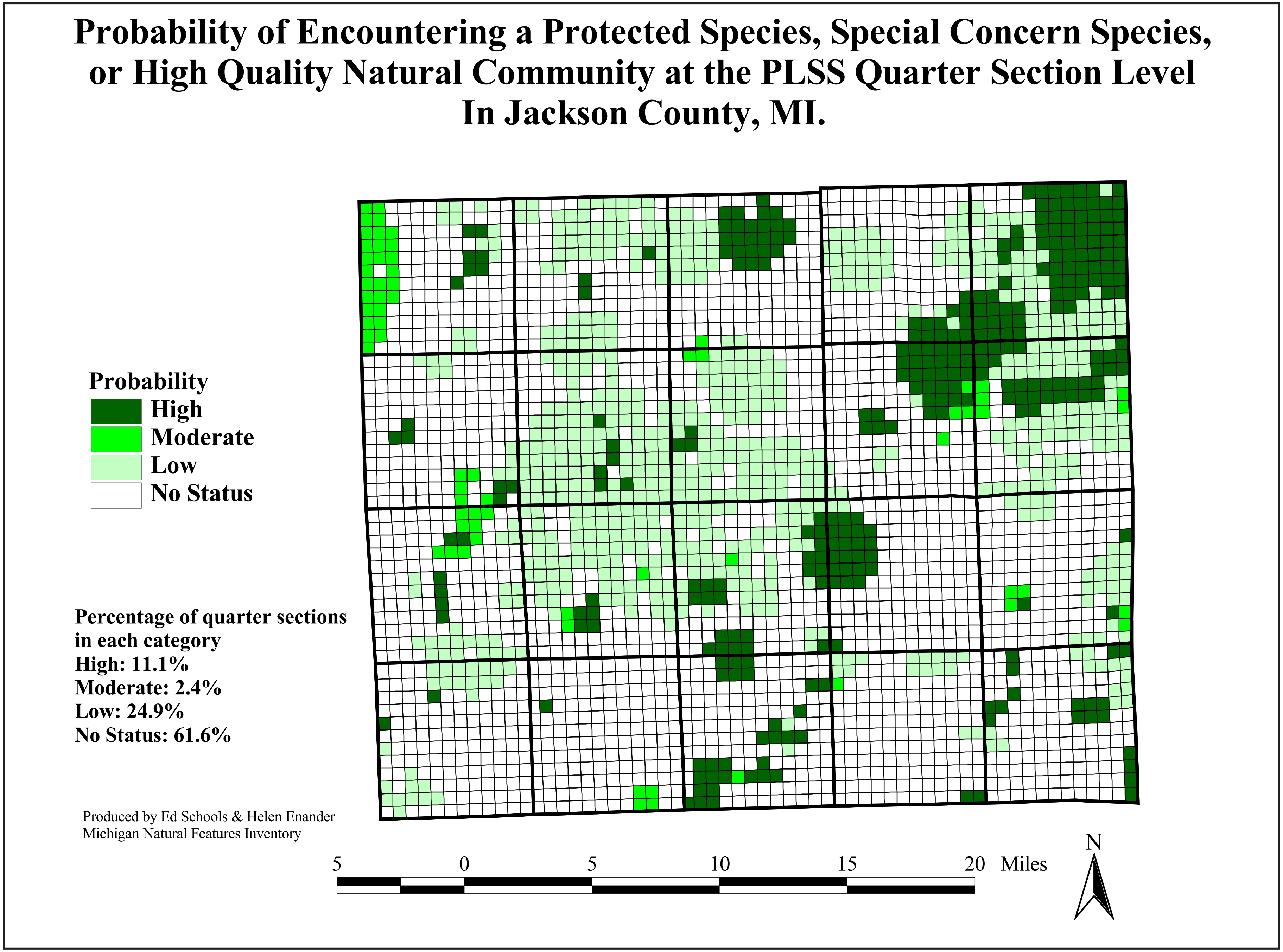

Figure 7: Probability values in Jackson County at the PLSS quarter section resolution

Biodiversity scores of Jackson County MI. at the PLSS quarter section resolution

Higher scores imply greater biodiversity value

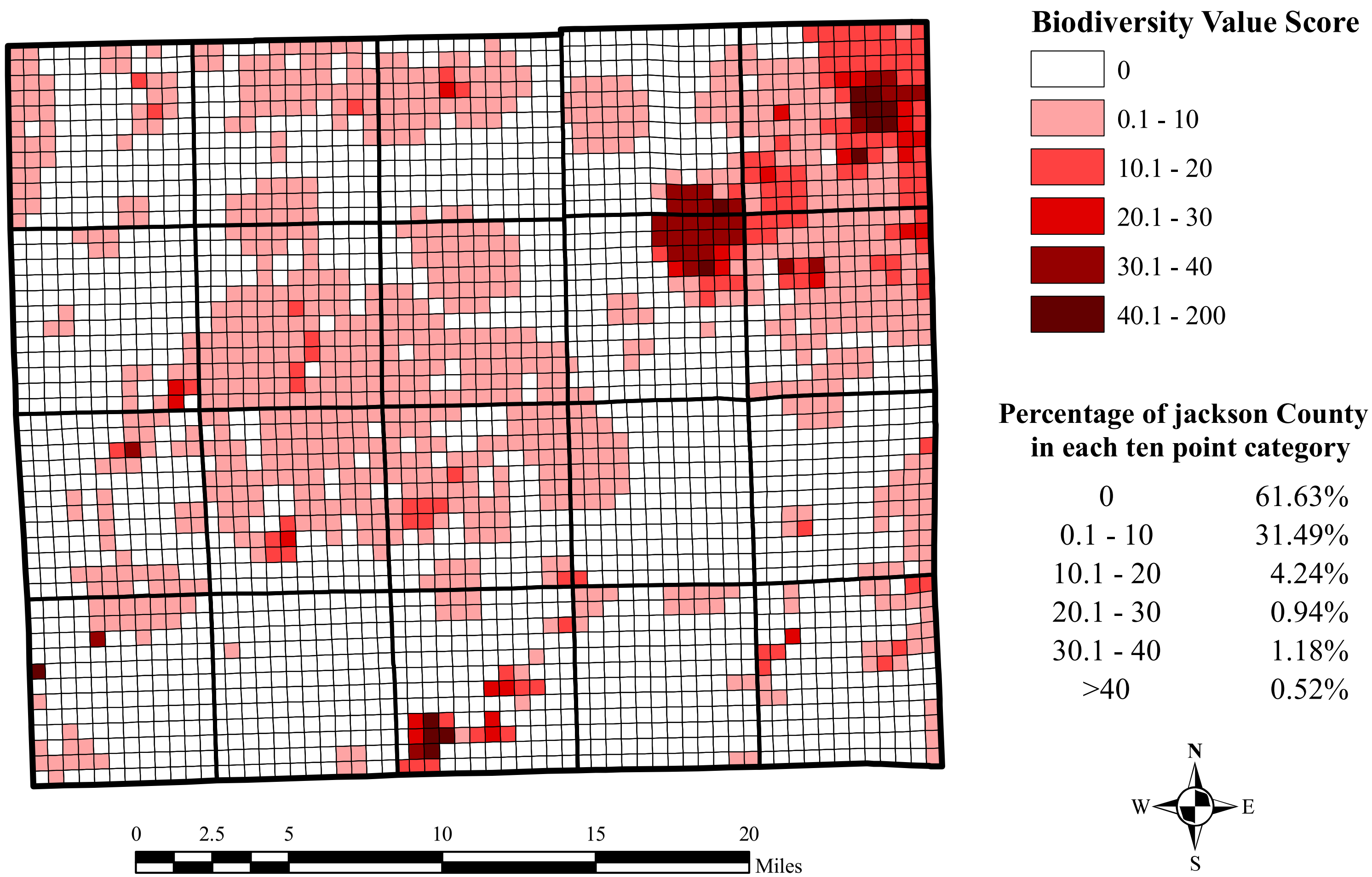

Figure 8: Biodiversity values in Jackson County at the PLSS quarter section resolution

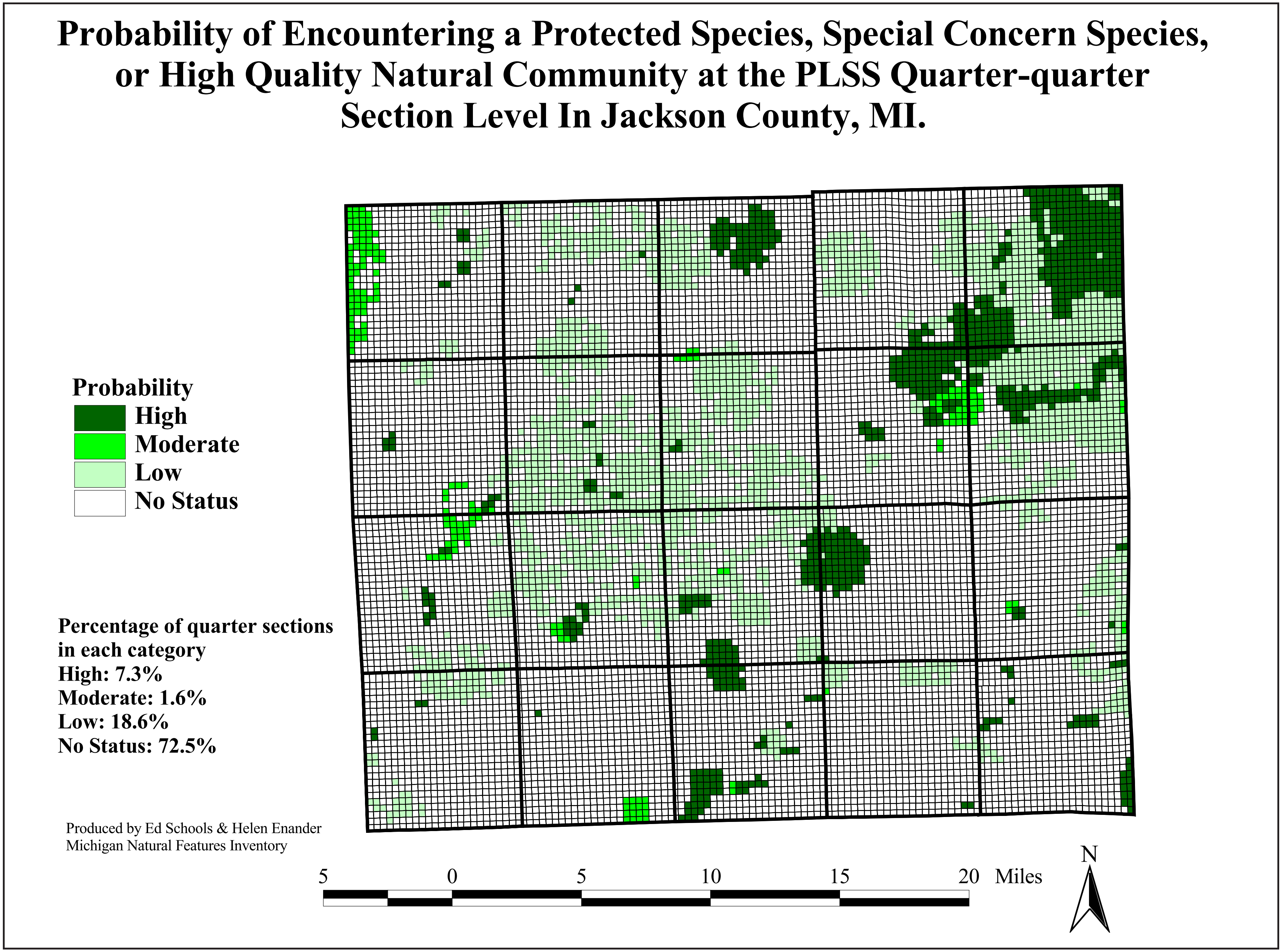

Figure 9: Probability values in Jackson County at the PLSS quarter-quarter section resolution

Biodiversity scores of Jackson County MI. at the PLSS quarter-quarter section resolution

Higher scores imply greater biodiversity value

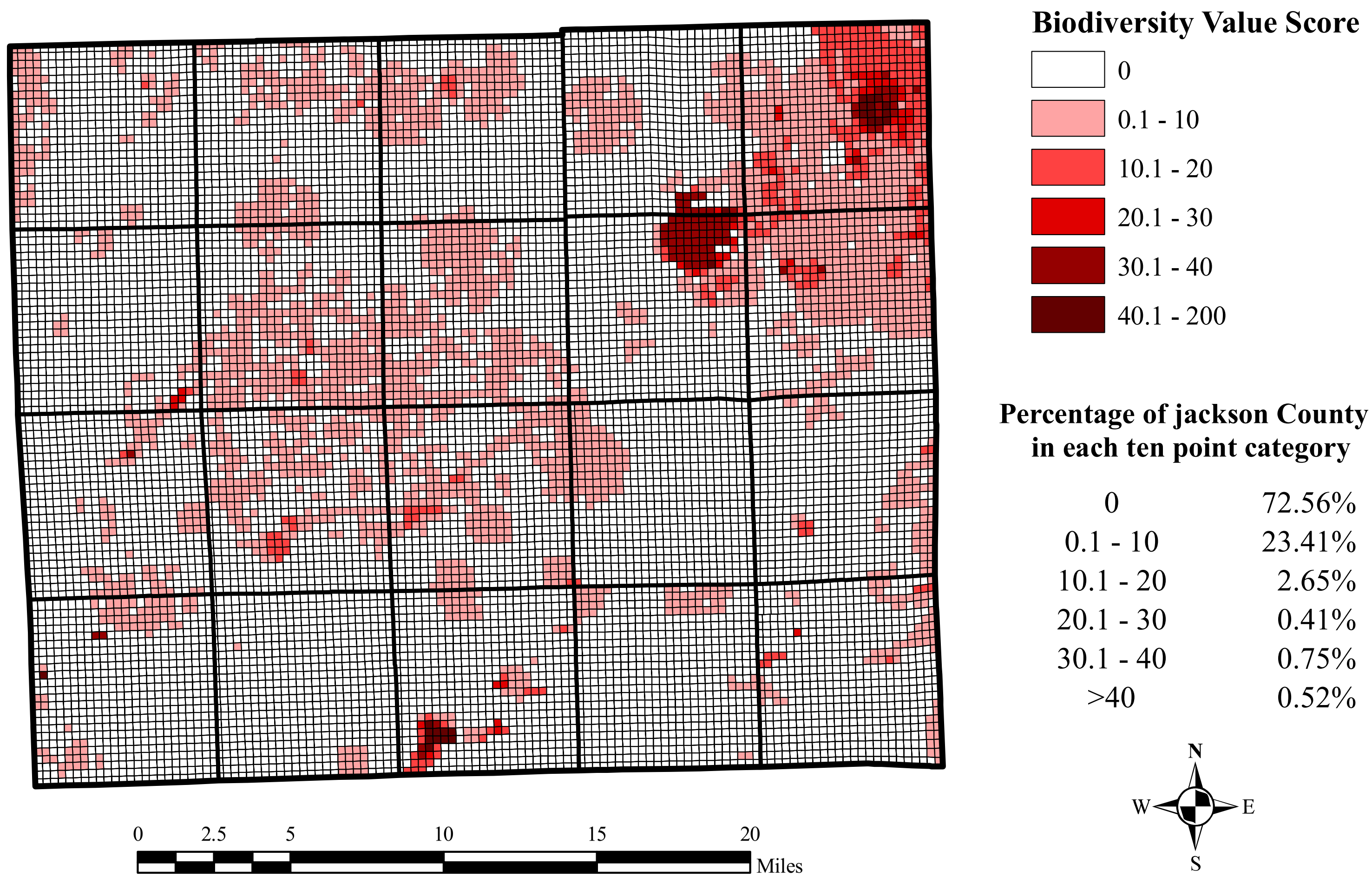

Figure 8: Biodiversity values in Jackson County at the PLSS quarter-quarter section resolution

planning efforts the PLSS grid is a natural choice. Defining the proper spatial resolution of these models requires balancing data sensitivity with the need for useful information. Generally, the finer the spatial resolution is, the more meaningful the information. Figures 5 through 10 demonstrate this for Jackson County. The models presented at the quarter-quarter section (~ 40 acres) provide more detailed location information than when presented at the section (~ 1 square mile) resolution. While the section level resolution data may be appropriate for larger scale planning efforts, it is too coarse for individual site level project planning. Presenting finer resolution information in a public process, however, could draw unnecessary attention to a particularly sensitive area or an individual's property.

One solution is to utilize only the coarser level information in the more open public discussion and reserve the finer resolution information for regulatory authorities. The coarser information can be used in broader planning efforts to direct development away from areas likely to impact sensitive areas. When a project is proposed within a potentially sensitive area defined by the coarser information, the project can be checked against the finer resolution information. Those proposing the projects can be informed of potential impacts to sensitive areas and be given appropriate information on how to proceed. Because the model outputs are GIS layers, it is relatively easy to include them in a land use planning decision support system that will facilitate this process.

Habitat models

Habitat models are used to remove from consideration inappropriate areas within the known spatial extent of the more generalized species occurrences. Users should realize that the habitat models are generalized habitat models intended to eliminate clearly inappropriate areas from considerations. These generalized habitat models are deductive models based on expert information. They are not intended as statistically valid models of habitat occupancy.

There are several reasons why the habitat models are relatively simple. Habitat requirements for many species, e.g. land snails or insects, are not well defined. In many instances the resolution and attributes of existing data may not be specific enough for detailed habitat models. Often the habitat models represent a compromise between known species information and available datasets. For instance, a species requiring marl fen areas may have to be modeled using an attribute of herbaceous wetland in a land cover dataset. While the herbaceous wetland attribute may encompass more than marl fens, it will eliminate forested, urban, agriculture, and open water categories.

Land use/Land cover

The datasets used to create the habitat layers for the models can make a noticeable difference in the model outputs. Two different land use/land cover datasets were used for the models presented here. The models for Jackson County utilized the 1978 Michigan Resource Information System (MIRIS) land use dataset. All the other models utilized the 2000 Integrated Forest Management, Assessment, and Prescription (IFMAP) land cover dataset.

One can notice obvious differences between these datasets. The1978 MIRIS land use dataset is a photo-interpreted dataset with a minimum mapping unit of 2.5 acres (~one hectare). Any smaller area of a particular land use category is aggregated up into the category of the surrounding land use. The IFMAP land cover dataset is classified satellite imagery with an individual cell size (pixel) of 30 by 30 meters (900 meters2 or 0.22 acres). Individual pixels or small groups of pixels are not aggregated up into the surrounding land cover.

The differences between the two datasets can be easily seen in urban areas such as the City of Marquette (Figure 11). In the MIRIS land use dataset only areas greater than the minimum mapping unit of 2.5 acres are classified as something other than urban. In the IFMAP dataset, individual pixels of different land cover

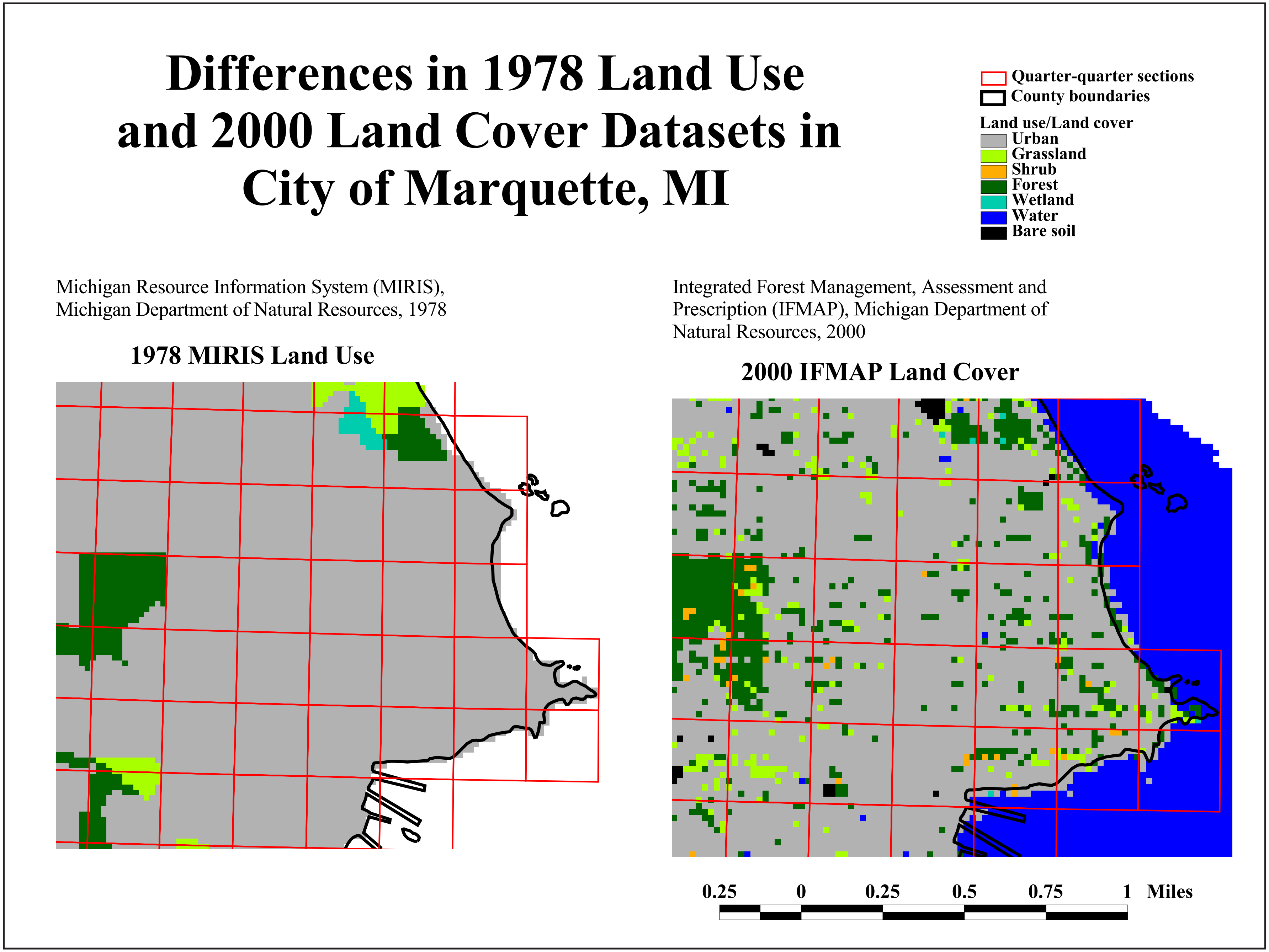

Figure 11: Differences between 1978 MIRIS landuse and 2000 IFMAP landcover datasets

types can be seen. In this example, when creating a habitat model for a forest dependent species, the individual pixels of forest cover will be classified as potential habitat. Any particular unit of interest intersecting even a single cell of potential habitat will be flagged as having a potential to harbor the species. The result is that heavily urbanized areas will be selected as having the potential to harbor forest dependent species. The same type of misrepresentation could occur when individual pixels of forest occur within an agricultural matrix or pixels of water occur within an urban area.

There are several ways to get around this issue when using a land cover dataset such as IFMAP. One could construct the habitat models using rules that eliminate isolated pixels of one classification that are surrounded by another classification. Another method would be to impose a minimum size criterion on all habitat polygons.

One should also consider the purpose of the models. They are intended to provide information about rare species to aid in land use planning. This type of information is essentially a moot point in already urbanized areas. The species records that give a probability of a species within urban areas tend to be older records with a generalized spatial extent. While the probability model will show that there is some probability of a rare species occurring in an urban area, it is unlikely that there is sufficient habitat to support a viable species occurrence. When the probability is examined in conjunction with the corresponding biodiversity value, the biodiversity score will tend to lower values.

Local needs and constraints
These models are presented as a method of incorporating sensitive data into the land use planning process. Land use planning is a local process involving local stakeholders and decision makers. MNFI presents these models, and the parameters used in the models, as an appropriate interpretation of the MNFI data. That does not mean other interpretations of these data are invalid. Incorporating the priorities of local users into the modeling process may help insure that the models are accepted and utilized. Following are some examples of how these models could be modified by local users.

The MNFI database contains legally protected species as well as special concern species and high quality natural communities. Special concern species and natural communities have no legal protection. A different interpretation would be to use only the state and federally protected species in the models. The output from a model utilizing only legally protected species will serve to highlight those areas where there is the potential for regulatory concern. It would eliminate those areas that may be of biological concern but contain no legally protected species.

Another interpretation of the data would be to use different dates in the probability model. MNFI chose post 1982 records as having a high probability of sill existing. This date was chosen in part because that is the year MNFI scientists, trained in Natural Heritage methodology, began doing field surveys to populate the database. All records from prior to 1982 came from reliable secondary sources. Records prior to 1970 were given a low likelihood of still existing. There is no strong reason for choosing 1970. Arguments could be made for choosing 1950 as well as 1970. One could also chose a single date and determine all occurrences after that date have a high probability of still existing and all occurrences prior to that date have a low probability of still existing. Because the dates are also used in the biodiversity value model, changing the dates will also affect the results of the biodiversity model.

Nuances of biological information
There are several caveats that must be understood when utilizing the MNFI natural features database for land use planning. Users should understand the nuances of the MNFI database, or for that matter, any sources of biological information, when utilizing models derived from biological data. Various nuances including; lack of negative data, lack of systematic statewide survey, survey bias, lack of extrapolation to

areas not surveyed, and the temporal nature of biological data, should be considered when employing MNFI data.

The MNFI database is a positive sighting database. Every record represents a location where rare species or a high quality natural community is known to have been observed at one time. The source for every record is also recorded in the database. Not represented in the database is what is often termed "negative data." In this usage, negative data is where a survey has taken place, but no rare species were documented. The lack of a species observation, especially in appropriate habitat, is not evidence of absence. This only means that the species was not observed during that particular survey effort. This is especially true for animals that are cryptic or very difficult to detect or plants that survive for long time periods in the seed bank.

Coupled with the lack of negative data is the lack of a statewide systematic survey for rare species and natural communities. MNFI surveys are opportunistic in nature, typically occurring where funding dictates. The opportunistic nature of the survey effort, including the use of outside contributors of data, leads to a level of survey bias in the database. This is apparent in the southern portion of the Lower Peninsula, especially where university collections have added to the database (Figure 12).

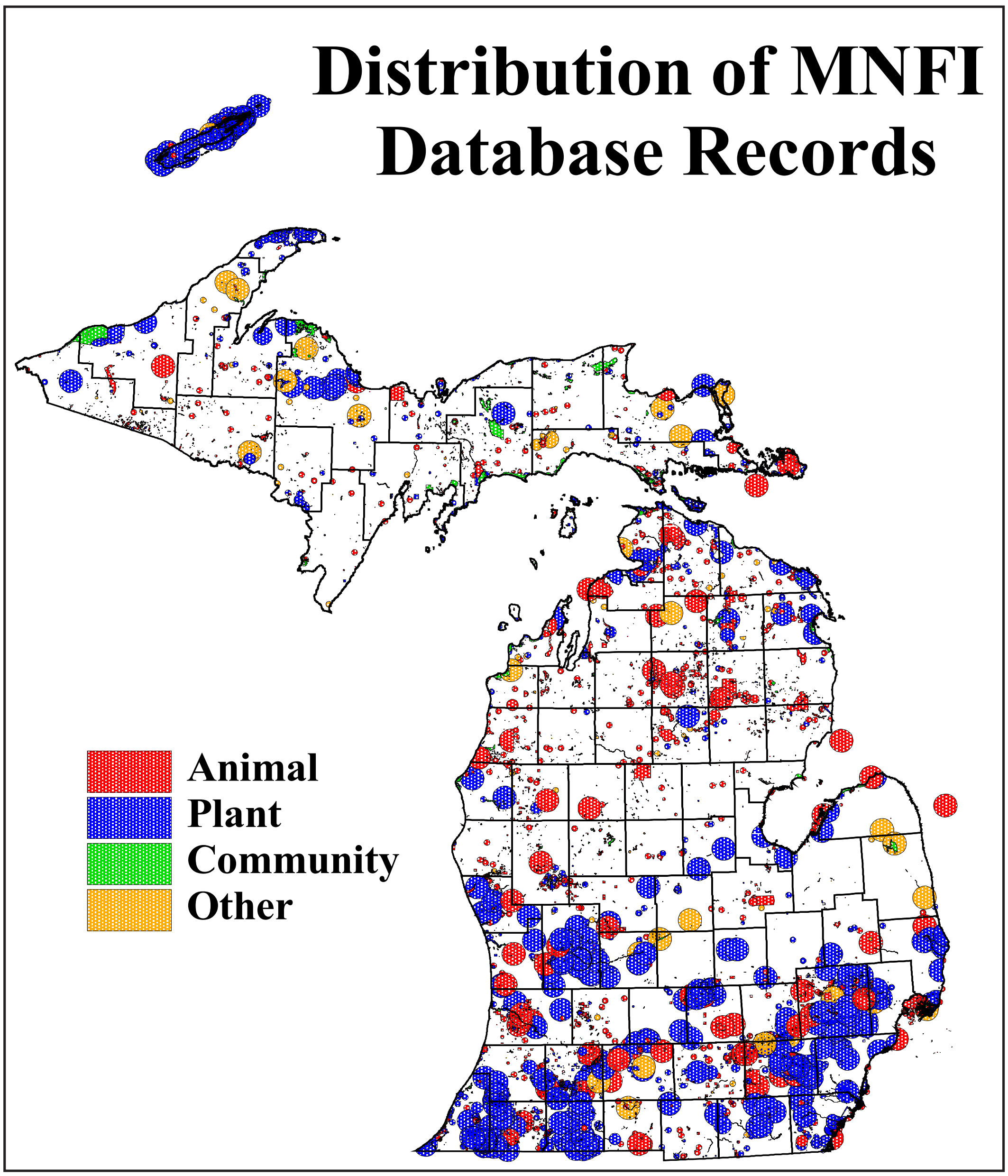

Figure 12: Distribution of MNFI database records

The effects of survey bias can be seen when comparing Oakland County to the Northern Peninsula counties. At the quarter-quarter section resolution, approximately 12 % of Oakland has a zero biodiversity value score or a no status probability value. This indicates that only 12 % of the county does not fall within the spatial extent of an occurrence. This can be contrasted with the Upper Peninsula counties that have range from 72% - 88% of the county not covered by the spatial extent of occurrences. Oakland County is, in fact, almost entirely covered by plant records that are historic and very generalized in their spatial extent. The more biologically important areas of Oakland County are captured in the less than 3% of the county that had a biodiversity value greater than 20 points.

These models are based on known and documented sightings of rare species. The models make no inference or extrapolation of known information into those areas with no documented occurrences. Because of the lack on negative data and the lack of systematic survey, users should not interpret a no status probability or a zero biodiversity value to indicate that no rare species or natural communities are present. Rather, these values should be interpreted to indicate that we do not know if something is present in an area and no projection of potential occurrences has been made.

Finally, users should recognize the temporal nature of the MNFI database. The models presented here are a snapshot in time. They represent the status of the MNFI database when the models were created. The MNFI database, however, is not static. The database is dynamic, constantly being changed and updated to incorporate new information or refine existing information. Understanding the dynamic nature of the database is important, especially when utilizing the models in a decision making process that spans a length of time. Use of these models should incorporate a mechanism that allows for the most current information to be utilized in the models.

Conclusions

The intent of these models is to provide information for land use planning while minimizing data sensitivity issues. The models presented here will perform as intended as long as the users are aware of the caveats inherent in using biological information. These models can be implemented as presented or the methodology can be tailored for local jurisdictions.

The probability model and the biodiversity model should be used in conjunction with each other. While they are both based on the same underlying dataset, they provide different information. The probability model indicates those areas where there is a high likelihood of encountering a rare species or high quality natural community. This model can help direct development away from those areas with known occurrences of rare species, minimizing potential regulatory problems and helping to protect biodiversity. The probability model cannot, on its own, help to prioritize areas for protection. The biodiversity value model, by scoring areas for their contribution to biodiversity, can help prioritize areas for conservation. Scores in the biodiversity value model cannot, however, indicate the likelihood of encountering a rare species. The scores in the biodiversity value model are also biased toward the more imperiled species. While the model may direct attention to those areas with higher scores, areas with lower scores still have the potential to harbor species with legal protection.

Land use planning is a local decision. In Michigan, most land use planning and decision making occurs at the township level. Local decision makers, and those affected by the decisions, must determine what is important to them and how they would like to incorporate MNFI data into their planning decisions. MNFI can, and should, play a role in helping a community determine the significance of the natural features in the community's jurisdiction and how best to incorporate that information into the decision making process.

Contact information: Ed Schools, Michigan Natural Features Inventory, 517-347-0862, schoolse@michigan.gov or schools@msu.edu.

Appendix A

Descriptions of Global and Subnational Ranks

Global Rank (GRANK): The priority assigned by NatureServe (www.Natureserve.org) for data collection and protection based upon the element's status throughout its entire world-wide range. Criteria not based only on number of occurrences; other critical factors also apply. Note that ranks are frequently combined.

G1	Critically imperiled globally because of extreme rarity (5 or fewer occurrences range-wide or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.
G2	Imperiled globally because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.
G3	Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g. a single western state, a physiographic region in the East) or because of other factor(s) making it vulnerable to extinction throughout its range; in terms of occurrences, in the range of 21 to 100.
G4	Apparently secure globally, though it may be quite rare in parts of its range, especially at the periphery.
G5	Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
GH	Of historical occurrence throughout its range, i.e. formerly part of the established biota, with the expectation that it may be rediscovered (e.g. Bachman's Warbler).
GU	Possibly in peril range-wide, but status uncertain; need more information. GX = believed to be extinct throughout its range (e.g. Passenger Pigeon _ with virtually no likelihood that it will be rediscovered.
GX	Believed to be extinct throughout its range (e.g. Passenger Pigeon) with virtually no likelihood that it will be rediscovered.
G?	Incomplete data.
Q	Taxonomy uncertain.
T	Subspecies.
U	Unmappable through out the global geographic extent.
?	Questionable.

SRANK: The priority assigned by the Michigan Natural Features Inventory for data collection and protection based upon the element's status within the state. Criteria not based only on number of occurrences; other critical factors also apply. Note that ranks are frequently combined.

S1	Critically imperiled in the state because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extirpation in the state.
S2	Imperiled in state because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extirpation from the state.
S3	Rare or uncommon in state (on the order of 21 to 100 occurrences).
S4	Apparently secure in state, with many occurrences.
S5	Demonstrably secure in state and essentially ineradicable under present conditions.
SA	Accidental in state, including species (usually birds or butterflies) recorded once or twice or only at very great intervals, hundreds or even thousands of miles outside their usual range.
SE	An exotic established in the state; may be native elsewhere in North America (e.g. house finch or catalpa in eastern states).
SH	Of historical occurrence in state and suspected to be still extant.
SN	Regularly occurring, usually migratory and typically nonbreeding species.
SR	Reported from state, but without persuasive documentation which would provide a basis for either accepting or rejecting the report.
SRF	Reported falsely (in error) from state but this error persisting in the literature.
SU	Possibly in peril in state, but status uncertain; need more information.
SX	Apparently extirpated from state.