HABITAT MAPPING AND REMOTE SENSING FOR RARE, ENDANGERED, AND SENSITIVE SPECIES IN THE HUDSON VALLEY, NY

David Jakim and Lawrence McGlinn
Department of Geography
SUNY-New Paltz
New Paltz, NY 12561

ABSTRACT: *Biodiversity is a critical indicator of the health of a local or regional environment. An important first step in biodiversity assessment is the creation of a large-scale habitat map for a region of interest. In the present study the authors create a large-scale, field-verified habitat map of a varied landscape of nearly 4000 acres in the central Hudson River Valley of New York State. The study area is defined by north-south trending swamp-marsh complexes, in many cases dammed by beavers, bordered by development, or more rarely by upland forests, ledges and mountains. Of particular interest is the presence of rare and development-sensitive species in the study area. The map generated by the authors was compared with a simple supervised classification of the same area using Landsat Enhanced Thematic Mapper data. A pixel-by-pixel overlay of the supervised classification with a simplified habitat map shows 45% pixel misclassification. However, the supervised classification did identify each of the significant habitats in the study area, though not with perfect spatial correspondence. Our conclusion is that remote sensing holds promise for simplifying the process of habitat mapping, leaving more time for researchers to work in the field.*

Keywords: *Biodiversity, Habitat, Remote sensing, Rare species, Hudson Valley*

INTRODUCTION

The importance of biodiversity in the environment has come to be widely accepted over the last three decades. Biodiversity has been recognized as an indicator of ecosystem health, a reservoir for agricultural variety, a source of medicines, a supporter of watershed quality, a mediator against human disease and disease vectors, and an aesthetic and recreational resource (Myers 1996; McNeely and Scherr 2003; McChesney 1996; Schmidt and Ostfeld 2001; Farnham 2007).

Researchers use habitat maps as the first step in assessing biodiversity, assessing habitats as places where biological communities live and interact with abiotic features. The mosaic of a well-classified habitat map is the best tool we have for describing, understanding, and predicting patterns of biodiversity. Quality habitat maps aid in identifying the locations of rare species communities. Some rare species have adaptations that may be critical for future ecosystem health and also provide educational value. Knowledge of rare species, especially in more obscure taxa such as insects, fungi and nematodes is relatively sparse and thus has educational value. In the habitat approach, rare species populations and distributions are field checked based on their known affinity to certain habitats and habitat characteristics, but the lack of habitat data is one of the biggest drawbacks of this method. Producing a detailed, accurate habitat map is time-consuming, even for well-trained analysts. Typical large-scale habitat-mapping involves air photo interpretation combined with ground truthing, and manual drawing. Such maps are difficult to update as habitats change. Moreover, the process of producing them can consume years of work for a group of analysts to map a single town.

A high-quality, large-scale habitat map created through digital remote sensing would allow concerned parties to spend less time mapping habitat and more time conducting habitat quality, rare species surveys and conservation efforts. It would also allow for much wider spatial coverage, perhaps identifying critical habitats in areas not originally targeted by landowners, officials, and volunteers. Digital remote sensing has been commonly used to produce land cover maps, most notably the National Land Cover Database 2001, an effort by a consortium of federal agencies to map land cover for the entire country (Homer et al 2004). Also, a combination of high resolution satellite imagery, combined with aerial photography, has been used to yield a detailed urban land cover map of Beijing, China (Tang 2003). However, less literature exists on the more specific requirements of habitat mapping for biodiversity assessment. Remote sensing models predicting the location of indicator species have been developed for small-scale, global analysis of biodiversity (Soberón and Peterson 2004). Supervised and unsupervised classification has been used to define forest habitats (Innes and Koch 1998) and to measure plant species richness (Gould 2000). Supervised classification of Landsat TM data has also been used to assess grassland quality in the Great Plains (Lauver1997).

This paper is an answer to the call of Ferrier (2002, 331), who urged biodiversity researchers to "use relatively data-rich regions as test-beds for evaluating the performance of surrogates that can be readily applied across data-poor regions." First - data richness - the paper details the process and the value of producing a fine-scale, field-verified habitat map in a rich, fragmented biodiversity area in southeastern New York State. Second - the surrogate - this paper reports results of a test of a supervised classification of Landsat ETM data for the study area. This classification is the first step in developing methods to simplify high-quality habitat map production that can ultimately extend into data-poor regions.

STUDY AREA AND RESEARCH METHODS

The study area for this project is along the Swartekill, a stream that bridges the towns of New Paltz and Lloyd, NY. It was chosen based on the findings of the Metropolitan Conservation Alliance's (MCA's) publication *Northern Wallkill Biodiversity Plan* (2007) that outlines 17 biodiversity areas in the two towns. These biodiversity areas were delineated based on the presence of rare and development-sensitive species, the size of the area (>600 acres), a high degree of connectivity with other biodiversity areas, and a low degree of internal fragmentation and human disturbance. Our 4100-acre study area includes three of the biodiversity areas studied in the report: the Northern Swartekill, Central Swartekill Wetland (also known as Plutarch Swamp), and Hawleys Corner's Wetlands Biodiversity Area (Figure 1). These tracts were singled out by the MCA as being in need of further study. We also chose the area because of its connectivity to other large, important habitats such as Chodikee Lake and Vicinity Biodiversity Area to the east (Labruna and Klemens 2007).

The study area is defined by north-south trending swamp-marsh complexes with streams running through them, in many cases dammed by beavers, bordered by development, or more rarely by upland forests, ledges and mountains. Three peaks of the Marlboro Mountains are located in the northeast of the study area and through them our study area connects to thousands of acres of contiguous undeveloped land to the northeast. The Shawangunk Mountains, 10 miles west of the study area, form an even larger undeveloped wilderness. A variety of rare plants and animals take refuge in these places and depend on the inaccessibility of the terrain for their survival. The lesser slopes of these mountains are mostly developed. Topographically low upland forests, where the majority of the human population lives, are highly fragmented or limited in extent. Of the of 4100 acres of land in the study area, hardwood swamps make up about 35%, upland hardwood forests 31%, and development 11%.

Most of the forests in New Paltz and Lloyd started growing during the 1940s, when the 90% of the Hudson Valley that was open agricultural land, began transforming into what is now second growth forest. Close to 25% of the habitat in our study area is in the state of ecological succession from meadows and farmland to shrubby old fields, to mixed cedar-hardwood successional forests, to upland hardwood forests. These are important habitats that need to be managed for a range of species, including rare herbaceous plants, birds, butterflies, moths, dragonflies and skippers. Trees of these "second-growth" forests typically have diameters of 15-20 inches at chest height. Trees of "old-growth" or mature forests are rare and typically have diameters of 20+ inches at chest height. Since the decline of agriculture in the area, developers have paved or built over significant swaths of land and greatly fragmented it. The biodiversity value of cultivated land may be restored within a human lifetime, but paved land takes many generations to return to a state of ecological health.

More than 95% of the streams in the study area discharge to the Swartekill, which flows north, joining the Wallkill River as it enters the Hudson River. Streams are habitat connectors that aid in the dispersal of many species. As is common throughout the United States, many diverted and channelized streams are the result of historic and present-day human wetland drainage.

In the field, we became familiar with the study area by making frequent visits, taking pictures, and taking GPS readings to orient ourselves. During the field verification of habitat phase in the summer of 2008, we visited over two-dozen parcels of 10-150 acres size and conducted qualitative biodiversity assessments of habitats we delineated remotely. We used the Categories of Endangered and Threatened species are defined in New York State Environmental Conservation Law section 11-0535. Endangered, Threatened, and Special Concern species are listed in regulation 6NYCRR 182.5. Explanations of New York State criteria and rankings of rarity are from the

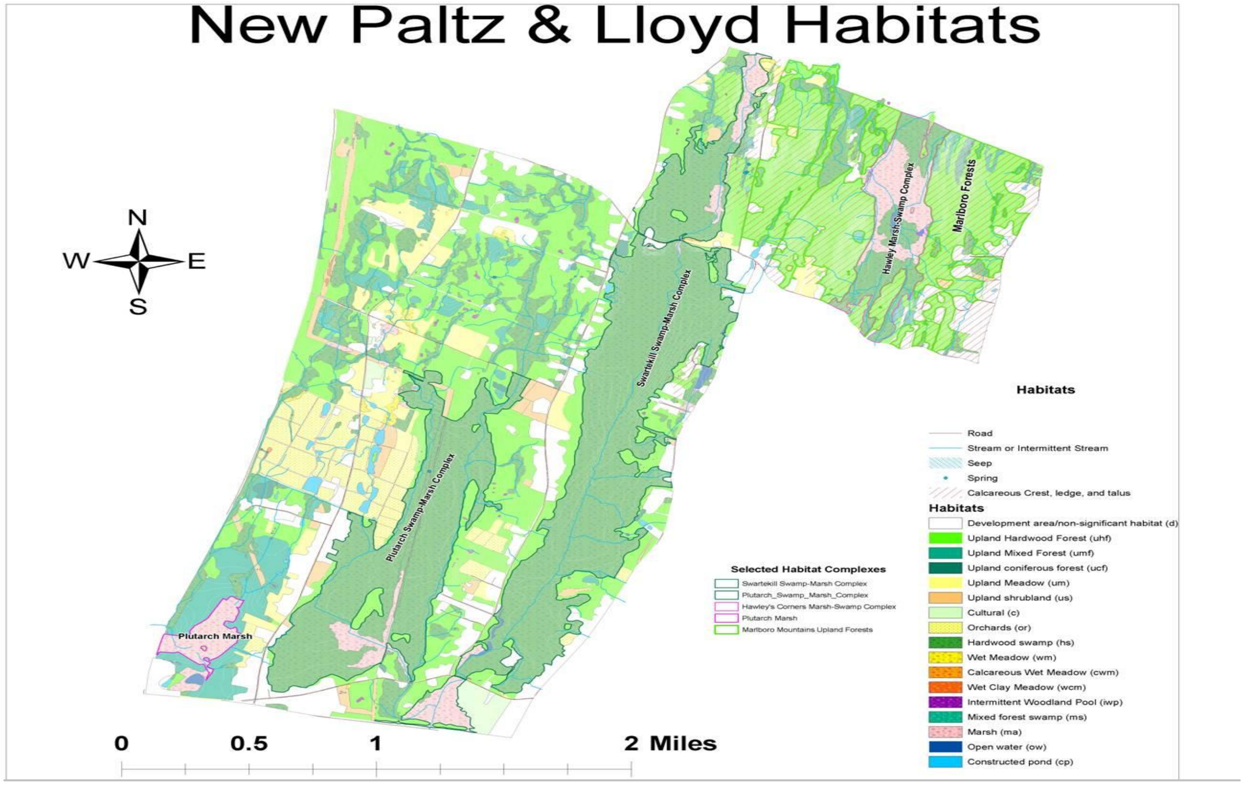

Figure 1. Habitats of the diverse ecosystem on the border between New Paltz and Lloyd, NY.

New York Natural Heritage Program (NYSDEC 2008).

In the lab, the detailed habitat map was manually digitized "heads-up" using a standard mouse and monitor, over a combination of stereophotos, orthophotos, a soil map, and DEM-generated contours of the study area. Then, areas of uncertainty were re-visited to verify the correct boundaries of habitats. Our model is the habitat scheme developed by New York State's Department of Environmental Conservation in concert with Hudsonia, Ltd.'s Biodiversity Resources Center (Kiviat and Stevens 2001; Hudsonia Ltd. 2008). We made an effort to map small habitats such as wet clay meadows, calcareous wet meadows, intermittent woodland pools and intermittent streams where rare plants and animals are disproportionately represented. Such small habitats are often overlooked in coarser land-cover and land-use maps.

With the map done and verified in the field, we turned to remote sensing to test how a supervised classification would define the habitats we established. Because we currently only have access to Landsat ETM data with 30-meter resolution, we combined the smallest habitats with neighboring habitats based on size, location and similarity to create a simplified map for comparison with the classification produced by remotely sensed data. For each of the six habitats created, we chose two representative training sites from a composite of bands 2, 3, and 4, (green, red and near IR) and ran the classification with a maximum likelihood classifier. We used Multispec32 remote sensing software to create our supervised classification. Multispec32 is a free package available for download from the Purdue Research Foundation (2007). Then, using ArcGIS spatial analyst, we overlaid each habitat from the supervised classification with the corresponding habitat from the hand-digitized, field-checked map, calculating the percentage of overlap.

RESULTS

Map and Fieldwork

The habitat map for this project was produced at a finer scale than similar maps have been in the past. Significantly, this precision allowed the inclusion of intermittent woodland pools, concentrated in the northwestern portion of the study area, and of calcareous crest, ledge, and talus, scattered throughout the diagonally hatched northeastern section of the study area where there is greater relief. Both habitats harbor rare species. Rare species have been known to use all of the habitat types including the fringes of developed areas/non-significant habitats, orchards, cultural areas, and roadside ditches, but this is extremely rare. Except for the box turtle, the rare species that we sighted occupied sites more than 500 feet from developments. Approaching development, high rates of human disturbance, development associated species, noise, light, altered microclimate and altered hydrology tend to favor invasive species at the expense of rare, declining, native or sensitive species of conservation concern. Habitat types in which rare species were found include: Calcareous Crest Ledge and Talus, Wet Clay Meadows, Upland Hardwood Forests, Intermittent Woodland Pools, and Hardwood Swamps.

Near development, particularly along the three paved, two-laned roads running north-south through the study area, habitats are extremely complex owing to human disturbance regimes, human-made habitats, and glacial geomorphology - including a mixture of glacial till - outwash and lacustrine features. North-south trending swamp-marsh complexes, such as the Swartekill, are largely the result of the north-south trending aspect of the Marlboro Mountains combined with human historic wetland filling for road construction and perhaps the impact of glaciations. We viewed Downy Rattlesnake Plantain (*Goodyera pubescens*) on the west bank of the Swartekill in the northern portion of the study area. It is a regionally rare orchid to the Hudson Valley listed by the State of New York as exploitably vulnerable (USDA 2008).

The Swartekill floodplain and nearby wetlands are known to have populations of the false hop sedge (*Carex lupuliformis*), which is listed as rare in the state. Also, similar habitats in the Hudson Valley are home to the goldenseal (*Hydrastis canadensis*), winged monkeyflower (*Mimulus atulus*), small-flowered agrimony (*Agrimonia parviflora*), all listed as rare in the state, and the regionally-rare green dragon (*Arisaema dracontium*). The **N**ew York state endangered northern cricket frog (*Acris crepitans)* is a species found in habitats with mats of floating vegetation, and is known to have satellite populations in marshes in or adjacent to the Swartekill (Kiviat and Stevens 2001). However, we did not see the frog in our investigations.

A linear utility corridor, mapped as upland shrubland, runs from the south central study area through the Plutarch Swamp-March Complex and then along the northwestern fringe of the study area. Its narrow width fragments forests and swamps and divides streams, impacting the area more than its width suggests. Roads, long driveways and ATV tracks have a similar effect, eliminating shade, raising daylight temperatures, and reducing soil moisture along their paths. Nevertheless, we viewed the box turtle (*Terrapene carolina*), rare in New York State, sunning in a puddle in a utility corridor near the New York Thruway. Rare mole salamanders including the Jefferson and blue-spotted salamanders, listed as rare in the state, and the development-sensitive spotted salamander species (Labruna & Klemens, 2007) were found at a number of intermittent Woodland Pools.

The northeastern part of the study area is dominated by the Hawleys Corners Wetland Biodiversity Area and the Marlboro Mountains. Hawleys Corners is considered significant because it is home to the Northern Cricket Frog, because it is not fragmented, and because it connects the Northern Swartekill Biodiversity Area with the Chodikee Lake Biodiversity Area to the southeast. On the crest ledge and talus of the Marlboro Mountains we saw plants that are associated with calcareous substrate. These include two isolated populations of the regionally rare walking fern (*Asplenium rhizophyllum*) on two of the larger west facing ledges of the north-easternmost mountain. Lyre leaved rock cress (*Arabis lyrata*) (host to a regionally rare moth species) was found on west facing ledges on multiple mountains. Downy rattlesnake plantain (*Goodyera pubescens*) was found scattered throughout the upland forests. We also found unusual plant communities on the east facing ledges and talus slopes of the northeasternmost mountain characterized by diverse climbing buckwheats (*Polygonum* sp.), diverse tick-trefoils (*Desmodium* sp.), diverse violets (Viola sp.), Red-Honeysuckle (*Lonicera dioecia*) a plant typical of much more extreme mountains. This community was called “unusual and worthy of survey for rare species.” (Kiviat 2008).

Remote Sensing

The supervised classification, based on training sites from the southern part of the study area on ETM bands 2, 3, and 4, yielded mixed but generally encouraging results. When overlaid with the field-checked habitat map discussed above, the rate of misclassified pixels was high (Table 1). Overall, only 55% of pixels were correctly classified. Upland forest and orchards were most overrepresented throughout the study area, while development, hardwood swamp, and upland meadow were underrepresented (Figure 2). Upland forest covers only 1417 acres on the field-checked map, yet it shows 1998 acres on the classification. Much of this area is misclassified from hardwood swamp, which covered 270 fewer acres on the classification than on the habitat map. Orchards covered almost twice as much area on the classification as on the habitat map. This is due to misclassification of development, specifically residential development,

Table 1. Cross Tabulation of Habitat Map Classes (rows) with Supervised Classification Classes (columns) (in acres)

Habitat	Correct Classification	Development	Hardwood Swamp	Marsh	Orchard	Upland Forest	Upland Meadow	Total
Development	85.36		104.46	20.63	99.14	173.23	8.96	491.77
Hardwood Swamp	722.15	13.23		40.97	27.62	606.35	6.72	1417.04
Marsh	112.51	5.85	47.08		6.20	14.59	0.72	186.94
Orchards	118.45	21.10	6.78	5.93		20.70	8.61	182.31
Upland Forest	1139.42	17.40	251.83	22.46	58.29		35.20	1524.60
Upland Meadow	20.52	25.36	15.02	3.35	52.08	43.37		159.71
Total	2198.42	168.30	1147.32	205.85	361.78	1997.65	80.73	3962.38

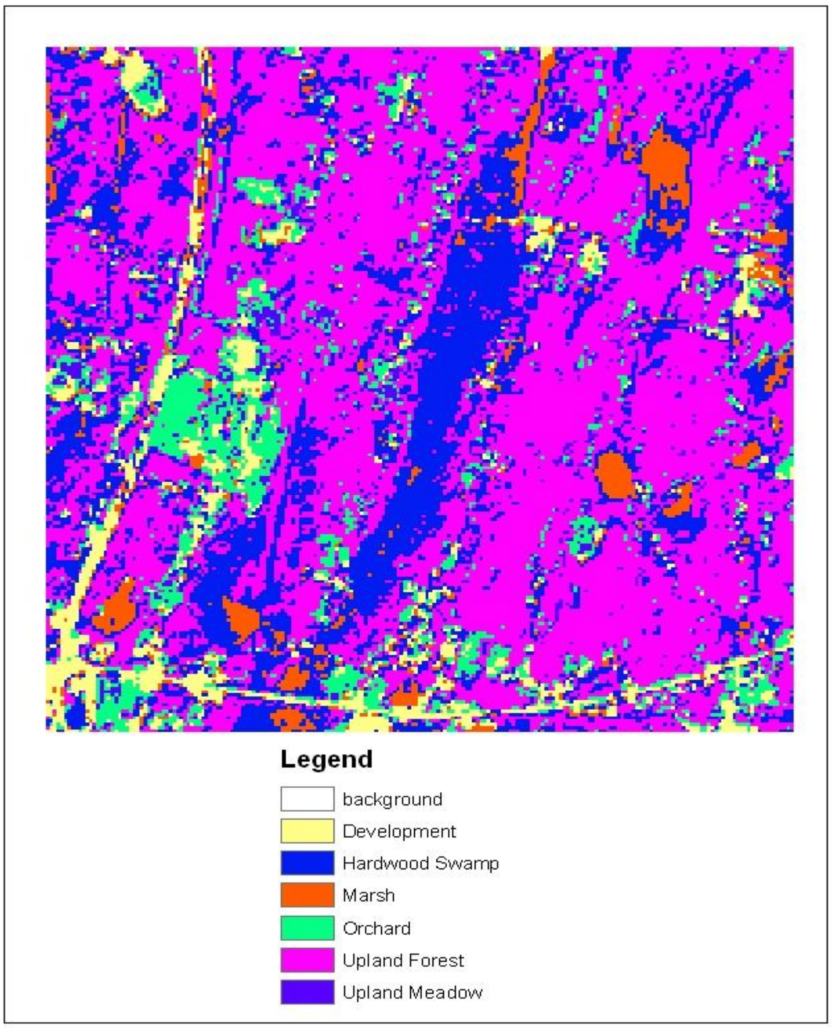

Figure 2. Supervised classification of study area (Landsat ETM data, 30-m resolution).

much of which is covered by scattered trees and grass, mimicking orchards. Only 168 acres of development showed up on the classification, compared to 492 acres on the habitat map. This is also partly due to the relatively small parcel sizes of development. With a spatial resolution of 30 meters, many smaller parcels were missed completely and misclassified in favor of the dominant background of upland forest.

A more significant and realistic goal of the classification would be to identify habitats of biological importance. Although the pixel-by-pixel correspondence between the habitat map and the supervised classification is low, the classification does identify all significant habitats in the study area. Plutarch Marsh, Hawleys Corner Swamp Complex, Swartekill Swamp-Marsh Complex, and the upland forests of the Marlboro Mountains are all clearly and accurately identified on the supervised classification as marsh, swamp, or upland forest. The Plutarch Swamp-Marsh Complex is less accurately identified, but it is roughly delineated as swamp. Even smaller habitats like the marsh along the Swartekill in the north-central study area are identified in the classification. It could thus serve as a rough guide for researchers who are going into the field to search for particular rare species of flora or fauna.

CONCLUSION

The results of this research show the value of a detailed habitat map and the potential for habitat mapping using a supervised classification of satellite data. Detailed fieldwork, exhaustive examination of aerial photos and careful hand digitizing created a reliable resource for a significant study area. Moreover, the map provided a baseline with which we have been able to test a simple supervised classification on public-domain software that can easily be taught and learned. The next step is to refine the classification. The satellites Quickbird and Geoeye produce multi-spectral imagery with much finer resolution than what we have used in this study - four meters vs. 30 meters (Toutin, T and P. Cheng. 2002; Nucci 2008), and the authors are working to acquire this data to run the supervised classification again on the study area, and, ultimately, to wider areas such as towns, counties, or entire drainage basins. Such data could help to produce maps that would include smaller habitats with a high likelihood of rare species, such as calcareous crest ledge and talus or intermittent woodland pools. It could also highlight significant areas of biodiversity that are not well known because of their isolation. There is considerable development pressure throughout the Hudson Valley/Shawangunk region, and both the state and local governments who are trying to deal with growth responsibly are keenly interested in species conservation. The one created for this study is a valuable tool for resource managers, and the methods we propose to simplify and hasten the production of habitat maps may lead to much broader map coverage in the near future. The ultimate goal is to establish a method for producing reliable, precise habitat maps over broad areas of the Hudson Valley and beyond.

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