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# LAND USE / LAND COVER PATTERNS OF BALD EAGLE (*Haliaeetus leucocephalus*) NESTING HABITAT IN THE NORTHERN LOWER PENINSULA OF MICHIGAN

By

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## ABSTRACT

LAND USE / LAND COVER PATTERNS OF BALD EAGLE (*Haliaeetus leucocephalus*) NESTING HABITAT IN THE NORTHERN LOWER PENINSULA OF MICHIGAN

By

Carrie Rose Steen

A GIS was used to determine if a pattern in bald eagle nest areas and reproduction exists in relation to land use / land cover patterns in Michigan. Habitat analyses were conducted at three level: nests sites in the Black River Watershed, breeding areas in the northern lower peninsula and nest sites in the northern lower peninsula (NLP) of Michigan. I examined the change in land cover over time, proportion of land cover types in nest and breeding areas and the relationship between nesting and production associated with surrounding land cover. I used 1993 GAP land cover data to develop a habitat model for nests in the NLP. Over all scales, bald eagles preferred land cover that included lowland forested areas, and avoided land cover that included urban and non-forested areas. Logistic regression models demonstrated distance to water as the most important variable in nest location. Results suggest that proportions of land cover types among nests is highly variable, but general nest site preferences do not seem to be changing. As the eagle population continues to expand, the availability of optimal breeding areas will decrease, and breeding pairs settling in sub-optimal areas may experience lower reproductive rates. Results of the analyses and methods that were developed should provide information useful in identifying future potential habitat for nesting bald eagles in Michigan.

But you never were made, as I,
On the wings of the wind to fly!
The eagle said.
*Will Carleton*

To all those who kept me grounded

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# CHAPTER 1

# SPECIES DESCRIPTION AND HISTORICAL TRENDS

## *Natural History and Distribution*

As one of the most widely distributed and well recognized raptors in North America, the bald eagle (*Haliaeetus leucocephalus*) has been the subject of much study and observation. It is estimated that prior to European settlement, there were a quarter million to a half million eagles throughout the continent (Gerrard and Bortolotti 1988). Although the species has undergone dramatic population fluctuations since, current geographic distribution is similar to historic distribution. Because the main food source for bald eagles is fish, they are primarily associated with areas of extensive aquatic habitats such as coastlines, major rivers and lakes. Breeding occurs across most of Alaska, Canada and the contiguous United States (U.S.), while wintering birds tend to congregate mostly in the lower 48 states where open water can be found.

As the second largest raptor on the continent, the size of the bald eagle ranges widely, weighing 3.0 – 6.3 kg (~ 6.5 – 14 lbs.) and having a wingspan of 168 – 244 cm (~ 6 – 7 ft.) (Buehler 2000). These large birds build equally impressive nests, generally ranging 1.5 – 1.8 m in diameter and 0.7 – 1.2 m tall. The nest structure is constructed primarily of twigs placed just below the crown of a live, overstory tree (Buehler 2000). Due to their size and preference for fish, bald eagles typically nest in mature, forested areas within 3 km of shallow ($\leq 2$ m) water (Buehler 1995). High foliage height diversity and relatively open canopies characterize forest tracts where eagles nest (Buehler 2000).

Nests occur in a variety of tree species, both coniferous and deciduous, varying in height from 20 to 60 m (x = 82 cm dbh, 28 m tall), providing adequate cover while allowing good visibility and flight access (Buehler 2000). A pair may maintain and reuse alternate nests within its breeding area, with as many as seven nests at a time associated with one breeding pair (Postupalsky 1983).

In the upper Midwest, nest building typically begins in February, with 1 – 3 eggs laid in March or April and incubated for 35 days. Successful nests may produce 1 – 3 young, which fledge at 8 – 14 weeks of age. After dispersal, immature eagles tend to range through the summer and wintering areas typical of their particular population, although there does not seem to be much fidelity to any specific site. This period generally lasts until maturity is reached at 5 – 6 years. At maturity, the eagle attains the signature full white head and tail plumage and is ready to begin breeding (Weise 1998, Buehler 2000).

*History and Status in the United States*

While it is impossible to know how many eagles existed in pre-settlement U.S., it is believed that there were 25,000 to 75,000 breeding eagles in the lower 48 states when the bird was adopted as the national symbol in 1782. At this time, the eagle population began to experience habitat degradation due to expanding settlement, and shooting mortality justified by the exaggerated perception that they killed livestock and posed a threat to salmon fisheries (U.S. Fish and Wildlife Service (USFWS) 1995). In fact, Alaska posted a bounty on bald eagles in 1917, further encouraging their destruction. This combination of factors led to a noticeable decline in the population by the early

1900's. As people became more aware of the magnitude of the loss, the species began to receive increasing attention for its conservation.

The Bald Eagle Protection Act of 1940 and the 1953 repeal of the Alaska bounty law made direct harm, harassment, possession and trading of eagles illegal, but did not address habitat concerns or a future threat that was to have as devastating an effect. After a brief period of stabilization, the population again began a downward trend. Throughout the 1950's, the decline of bald eagle populations across the lower 48 states was accelerated by decreased reproductive success associated with the use of organochloride compounds such as dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyl (PCB). When the National Audubon Society conducted a breeding pair census in 1963, only 417 pairs were found in the lower 48 states (U.S. Federal Register 59:35585).

In 1967, the southern bald eagle (defined as those located south of the 40th parallel) was officially listed as endangered in the conterminous U.S. under the Endangered Species Protection Act (U.S. Federal Register 32:4001). The ratification of the newer Endangered Species Act (ESA) in 1973 mandated the national protection of a species and its habitat if its population levels were reduced to the point of possible extinction. The southern bald eagle carried its endangered status to listing under the new act. A proposed modification was finalized in 1978 that classified all eagles in 43 states as endangered, and threatened in the remaining five (Michigan, Minnesota, Oregon, Washington and Wisconsin) (U.S. Federal Register 43:6230-6233). Under authority of the ESA, recovery regions were designated (Michigan and 23 other states were included in the Northern States region), and working groups were assigned to develop a recovery plan for each region.

With the implementation of recovery plans, habitat protection and ban of DDT use in 1972, a 1994 census found 4,452 eagle pairs in the lower 48 states (U.S. Federal Register 60: 35999-36010). Based on this ten-fold increase in only 30 years, the species was reclassified as threatened in all 48 contiguous states in 1995. By 1999, population estimates exceeded 5,700 breeding pairs, with a consistent 8% average yearly increase for the previous 10 years. This prompted a proposal for delisting the species across the lower 48 states (U.S. Federal Register 64:36453-36464). The Bald and Golden Eagle Protection Act, the Migratory Bird Treaty Act and the Lacey Act would still protect the bald eagle from direct harm and illegal trade, but these do not offer complete habitat protection as does the ESA. As continued development increases land conversion, concerns arose that delisting may ultimately lead to a loss of suitable breeding areas. The 1999 proposal, while still active, has not yet been adopted and the bald eagle currently remains federally listed as threatened in the lower 48 states.

*History and Status in Michigan*

In pre-settlement Michigan, the bald eagle historically nested throughout the state where suitable habitat occurred. Through the early and mid-1900's, the population gradually declined due to loss of habitat, prey resources and direct control by humans (Barrows 1912, Brewer and McPeek 1991). By the early-1940's, it was estimated that approximately 50 breeding pairs existed in the state, with the species restricted to the northern half of the state by 1959 (www.michigan.gov/dnr). Although the federal Bald Eagle Protection Act helped stabilize Michigan's eagle population, the use of DDT during this time impeded the population's recovery.

The effect of DDT on raptors caused thinning of eggshells, and with thinner shells, eggs were likely to break before hatching. Due to this compound's accumulation in the Great Lakes, environmental persistence and bioaccumulation in Great Lakes fish, Michigan eagles were particularly affected. Even after the ban of DDT, reproduction in Michigan remained severely depressed, especially in pairs nesting near the Great Lakes and anadromous rivers (Bowerman 1993). To address this, an annual monitoring program was initiated in 1961, confirming low reproductive rates through the 1960's.

In 1974, Michigan legislators passed the Endangered Species Act (PA 203), and in 1976 the bald eagle was listed as threatened within the state. During the mid- and late-1970's, the number of bald eagles increased slightly and remained steady around 86 breeding pairs. By 1983, it was determined that a region-wide goal of 1,200 breeding pairs by 2000 was adequate to consider the bald eagle population fully recovered in the Northern States (Grier et al. 1983). Michigan was to contribute 140 breeding pairs to the total recovery goal.

Surveys conducted in Michigan in 1985 revealed 121 breeding pairs producing 0.97 young per occupied nest. The bald eagle population had shown a marked increase and continued to exceed the production levels necessary for population maintenance (0.7 young per occupied nest) (Postupalsky 1985). In the late-1980's, the Michigan Department of Natural Resources (MDNR) increased its own recovery goal to 300 nesting pairs based on historical bald eagle nesting records and the number of suitable territories still in existence (T. Wiese, MDNR, personal communication).

The goal of 300 nesting pairs was initially reached in Michigan in the mid-1990s, and the current status is 388 nesting pairs producing 352 young (0.93 young per occupied nest) in 2001 (Postupalsky 2001). Since the mid-1980's, nesting distribution has also expanded southward, and active nests have now been recorded in 61 counties (D. Best, USFWS, personal communication). The bald eagle currently remains listed as threatened in the state under the revised 1994 protected species list of the Michigan Natural Resources and Environmental Protection Act (Part 365 of PA 451). While the proposal for federal delisting and achievement of recovery goals is a sign of successful recovery in Michigan, it is expected to pose new problems in management. If the species and its habitat are not fully protected by law, then management will likely focus more on maintaining suitable bald eagle habitat within changing, and often conflicting, land use patterns.

Since the re-establishment of the bald eagle in Michigan has occurred in a time and location of continued or increasing human development, it is important to determine what factors have affected nest site selection. Monitoring efforts that began in 1961 have resulted in data collection on bald eagles for variables such as nest location and nest tree characteristics. In addition, nestlings have been banded has been done as a means of following population movements, determining productivity, and formulating population projections to determine long-term survival (T. Wiese, personal communication). Data collection and banding have continued and currently provide over 40 years of information on the decline and recovery of Michigan's eagles. This data set provides an excellent resource in determining patterns of bald eagle re-establishment, including how land use has affected recovery.

This study was an opportunity to analyze the dynamics of a population whose rapid expansion (after removal of the primary stressor, organochloride contaminants) has occurred in a landscape much different from what it had previously known. As both human and eagle populations continue to expand, variables such as level and time of disturbance (Wright 1986, McGarigal et al. 1991), spatial factors and habitat quality will continue to affect bald eagle distribution and productivity. The specific goal of this thesis is to examine the effects of land use / cover on nest site selection and reproductive success of bald eagles in Michigan.

*Key to Abbreviations and Definitions*

- NLP – northern lower peninsula
- SLP – southern lower peninsula
- UP – upper peninsula
- BRW – Black River watershed
- MDNR – Michigan Department of Natural Resources
- USFWS – United States Fish and Wildlife Service
- MIRIS – Michigan Resource Inventory System – digital land cover maps derived from 1:24,000 scale color-infrared and black-and-white aerial photographs
- GAP – GAP Analysis Project – digital land cover derived from classification of 30 meter Landsat Thematic Mapper imagery
- BA – bald eagle breeding area
- Nest, nest site – geographical location of an individual nest
- Nest area – area around an individual nest bounded by a 500-meter circle centered on the nest
- Breeding area – formally, "the local area associated with one territorial pair of eagles and containing one or more nest structures" (Postupalsky, 1983); for land cover analysis, this also contains the extended area that may provide potential foraging habitat
- Alternate nests – all nests within a single breeding area, only one of which is used for nesting in a given breeding season

- Occupied, active – evidence of breeding activity was observed; this includes a pair of adult eagles, one eagle observed incubating, new nest built or an old nest with signs of repair in the current season; may refer to either a single nest or breeding area
- Inactive – no evidence of breeding activity observed; includes situations where no eagles are seen, a pair is observed with one individual being immature with no breeding behavior exhibited or one or more immature individuals are observed; may refer to either a single nest or breeding area
- Successful, productive – young were observed fledged or adequate evidence was observed to have assumed fledging; may refer to either a single nest or breeding area
- Failed – pair observed at some stage of active breeding, with no evidence of young fledged; may include nest destruction, failure to lay or hatch eggs, or young not surviving to fledging; may refer to either a single nest or breeding area
- Activity center – weighted geographic center of a breeding area determined by the number of years each nest was in existence and the number of years each nest was active within a given time period

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## CHAPTER 2

## LAND USE / LAND COVER PATTERNS OF BALD EAGLE NEST LOCATION, ACTIVITY AND SUCCESS IN THE BLACK RIVER WATERSHED, MICHIGAN

### INTRODUCTION

Many studies have been conducted on the bald eagle in the United States. These studies cover a variety of subjects including contaminant and human disturbance effects on production, habitat use by non-breeding birds (sub-adults and wintering birds), foraging habits and population dynamics. Nest habitat characteristics have not received as much attention as these other factors even though nest sites are integral for reproduction and their protection and management are mandated by the ESA. In over 300 references used by Buehler (2000), approximately 20 focused specifically on nest site selection and nesting habitat. Of these, nesting habitat has been described primarily in the Pacific Northwest (Anthony and Isaacs 1989, Garrett et al. 1993), Northeastern U.S. (Andrew and Mosher 1982, Livingston et al. 1990) and Southeastern U.S. (Wood et al. 1989, Hardesty and Collopy 1990, Buehler 1995). However, bald eagle research in the Great Lakes region, particularly Michigan, has concentrated on contaminant effects (Bowerman 1993; Bowerman et al. 1994, 1998, 2000), response to human disturbance (Mathisen 1968, Grubb et al. 1992, Grubb and Bowerman 1997) and microhabitat variables such as nest tree characteristics (Grewe 1980, Mathisen 1983, Bowerman 1993).

In pre-settlement Michigan, the bald eagle historically nested throughout the state where suitable habitat occurred. Through the early and mid-1900's, the population gradually declined due to loss of habitat, prey resources, direct control by humans and low productivity due to environmental contaminants (Barrows 1912, Brewer and McPeek 1991). To address this, an annual statewide monitoring program was initiated in 1961, providing over 40 years of information on nest location and production. These data, coupled with the increasing availability of digital spatial data, provides an excellent resource for determining both spatial and temporal patterns of land use / land cover associated with bald eagle nest location and productivity. This study presents an analysis of nesting habitat of a population whose rapid expansion (after removal of the primary decimating factor, pesticides) has occurred in a landscape much different from what had previously been available. Specific objectives were to determine patterns of land cover preferences associated with bald eagle nest locations, temporal changes in nest site land cover and differences in land cover between active and inactive nests, and between productive and failed nests.

## STUDY AREA

The data on nest location and production have been collected across the state of Michigan. Because standard, annual data collection did not begin until after the species had become restricted to the north, the majority of eagle breeding locations are distributed throughout the northern Lower Peninsula (NLP) and the Upper Peninsula (UP). The present analysis focused on nest sites in the Black River watershed (BRW).

The BRW encompasses approximately 155,800 hectares in northern Michigan and includes parts of Cheboygan, Montmorency, Otsego and Presque Isle counties (Figure 1). Approximately half the watershed area is under state ownership in the


Fig. 1. Location of Black River Watershed bald eagle nest site study area in the northern lower peninsula of Michigan.

Mackinac State Forest. Land cover is predominantly aspen / white birch and associates, northern hardwoods and lowland conifers, which together comprise 47% of the watershed area (Figure 2). Although this area did not contain many eagle nests through the 1960's and 1970's, the area was the subject of a land use / land cover time series analysis (Rutledge 2001). The BRW data provide detailed land cover data in a GIS format, using the same classification system (Michigan Resource Inventory System (MIRIS)) for three time periods (1963, 1978 and 1992). This allowed examination of patterns in bald eagle nesting areas using more detailed land cover classes than that of other available Michigan spatial data during the entire time that nest locations and production have been monitored.

## METHODS

### *Data Preparation*

To use a geographic information system (GIS) for comparison of nest locations and associated land cover, a digital point file was created of all recorded bald eagle nest locations in Michigan. Nest locations were digitized in ArcView 3.2 (ESRI, Redlands, California) using a combination of GPS coordinates, public land survey description and additional reference notes. Nest points were checked against hydrology shapefiles to ensure that nests did not fall off shore or in the middle of a lake with respect to existing base maps. A USFWS biologist (D. Best, personal communication) was consulted to correct discrepancies (Appendix I).

The ArcView extension XTools (DeLaune 2001) was used to select nests falling within the study area by using the clip command to clip the BRW area from the statewide

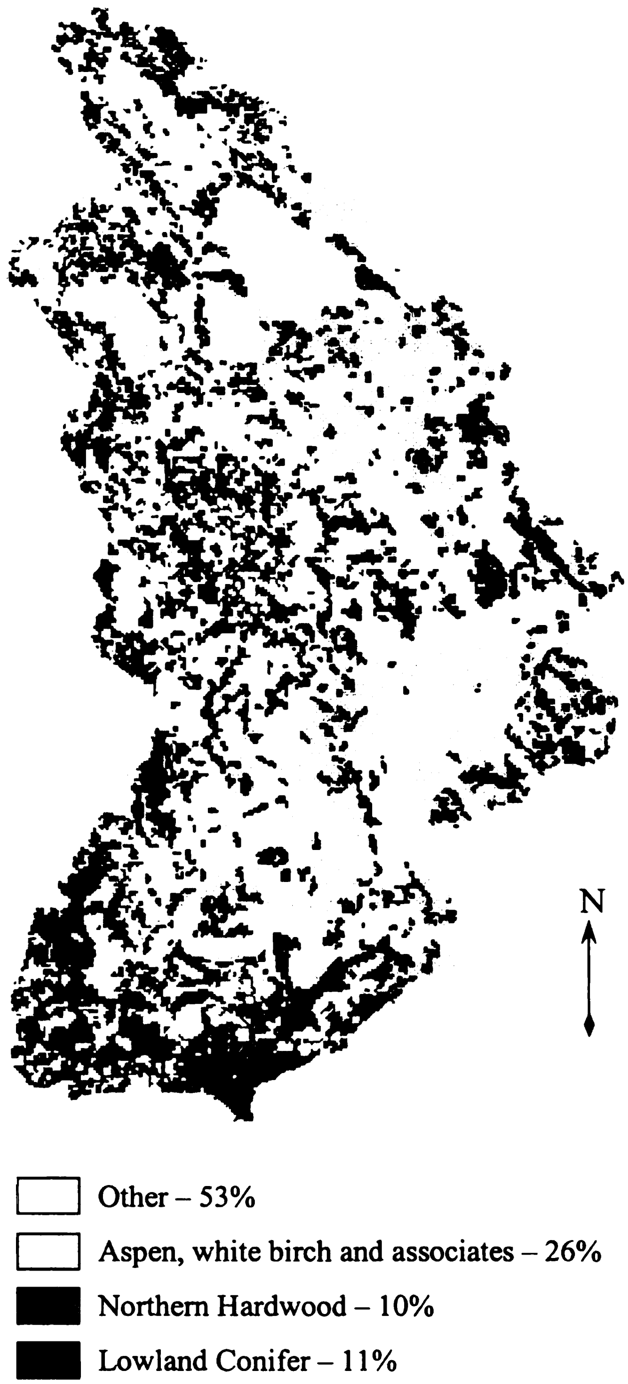


Fig. 2. Predominant land cover classes and percent of total area of the Black River Watershed, Michigan.

nest location coverage. Production, start year and end year records for these nests were used to determine whether each nest was active, inactive, productive or failed for each year it existed. Sample selection was further refined by using only those nests in the BRW that existed at some time within a three-year period centered on each land cover time step. This provided three 3-year time steps for nests (1962-1964, 1977-1979 and 1991-1993), maximizing sample size without temporally extrapolating land cover data too far.

These nests were further classified according to activity (A – active, I – inactive) and production (P – productive, F – failed). Because activity and production are variable across years for individual nests, only those nests that existed in the same year as the land cover data time steps (1963, 1978 and 1992) were used for activity and production analysis.

*GIS and Statistical Analysis*

Land cover was summarized by MIRIS level 4 cover class for the entire BRW area (Appendix II), and percent of total watershed area was calculated for each class for each year (1963, 1978 and 1992). Nest sites and associated land use / cover were evaluated by buffering each nest with a circular buffer of 500 m radius. This distance was chosen because most disturbance responses of nesting eagles to humans or conspecifics are induced within 500 m (Fraser et. al. 1985, Livingston et. al. 1990, Grubb et al. 1992). This distance is also comparable to a tertiary disturbance buffer zone described in the management guidelines of the Northern States Bald Eagle Recovery Plan (Grier et al. 1983).

XTools was used to intersect buffer zones for each nest time step with the associated land cover time step to determine land cover within 500 m surrounding each nest (Figure 3). The resulting nest site land cover was summarized by MIRIS level 4 cover class and percent area of each class was calculated for each nest area. Some land cover classes were combined because of the number of classes and range of values occurring in the BWR and nest sites. For example, for resource selection analysis, all wetland classes (i.e., emergent, scrub / shrub, forested) were grouped into one general wetland class. Percent cover class of combined nest area within each time step was also calculated as a means of initially determining which classes could be grouped or left out of further statistical tests.

Nest site land cover was also classified by time step and each of the 26 land cover classes occurring in nest areas were tested using a Kruskal-Wallis ($\alpha = 0.10$) to detect temporal changes in nesting land cover. Nests existing in multiple time steps were treated as separate occurrences since land cover around those nests may have changed over time, and this analysis is based on use of nests rather than just where they were initially placed.

To determine if nest site land cover had any significant affect on activity or production, nests from all time steps (1963, 1978 and 1992) were grouped. A Mann-Whitney U ($\alpha = 0.10$) was used to test land cover classes for differences within activity and production categories. Twenty-two land cover classes occurred in at least one nest area and were tested for active / inactive nest comparisons. Two classes (northern hardwood – no predominant and upland conifers – white spruce predominant) only occurred in nests that could not be classified by production category, leaving 20 land cover classes for productive / failed nest comparisons.


Fig. 3. Example of 500 m land use / cover buffer used to conduct bald eagle nesting habitat analyses in the Black River Watershed, Michigan.

Preference or avoidance in nest site land cover was analyzed using Resource Selection Analysis Software (Leban 1999). Nest area land cover compositions from all time periods were used. Similar cover classes were grouped providing 21 classes for analysis (Appendix II). Land cover composition of the entire BRW area was designated as available resource. The data matrix was prepared by pairing each nest area composition (used resource) with its corresponding time period's BRW composition (available resource). This was entered into the software and analyzed using the Neu method (Neu et al. 1974; $\alpha = 0.10$), which combines the use of chi-square goodness-of-fit analysis and construction of Bonferroni simultaneous confidence intervals. The result is preference, avoidance, or neither for each cover class based on where the predicted use value falls in reference to the confidence interval. For instance, if the lower confidence limit of used resource is greater than the predicted value, that class is considered preferred.

## RESULTS

Twenty-one nests existed in the BRW during the given time periods. All nests were used for use / availability and temporal analysis, 8 in 1962-1964, 3 in 1977-1979 and 10 in 1991-1993. Only 15 nests existed in the same years as the land cover data, leaving 9 active and 6 inactive nests for activity comparisons. Of the 9 active nests, one had an unknown outcome, leaving 3 productive and 5 failed nests for production comparisons. Over all time steps, 91 MIRIS Level 4 cover classes occurred within the BRW, and 32 occurred in nest areas. No time steps include all classes, indicating the addition and removal of some classes over time, and nesting areas in all time steps include < 34% of possible cover classes. The total number of cover classes occurring in nest areas was highest during the 1993 time step and lowest during the 1978 time step.

Percent total area of land cover classes was highly variable in all time periods, ranging from near zero to > 60% (Table 1). Of all cover classes occurring within the total nest area of any time step, most were only present in <50% of the nest sites (Table 2). Aspen / white birch, lowland conifers and northern hardwoods occur in the greatest percentage across the watershed, while aspen / white birch, lake and lowland conifer are greatest among the nest areas (Table 3). Only 4 other cover classes were present at nest areas during all time periods (scrub/shrub wetland, upland jack pine, lowland hardwood - aspen predominant, herbaceous). Twenty-two cover classes occurred at >2% of total nest area in at least one time period (Table 3). Only 7 of these classes occurred in nests areas in all time periods. All classes fluctuated greatly over time in nest areas even as they remained consistent in the watershed (Table 3).

Five classes (extractive – wells; northern hardwoods; aspen / white birch and associates; red pine; jack pine) showed significant changes over time ($P < 0.10$). The percent of all five classes changed within nest areas from 1963 to 1992 with northern hardwoods, aspen / white birch and associates, and red pine decreasing over time and extractive and jack pine increasing. Aspen / white birch also showed a significant decrease from 1978 to 1992 ($P = 0.02$) and red pine decreased both from 1963 to 1978 and 1978 to 1992 ($P = 0.02$; Table 4). No significant differences ($P > 0.10$) occurred in any land cover classes between active and inactive nests (Table 5). Only one cover class (extractive – wells) showed a significant difference ($P = 0.08$) between productive and failed nests, occurring in greater proportion in productive nests than in failed (Table 5).

Table 1. Number of cover classes, and minimum / maximum percent total area of land cover classes occurring in each time step in the Black River Watershed, Michigan and bald eagle nest areas within the watershed.

| | Time Step | # MIRIS Level 4 Land Covers Classes | Minimum % Area | Maximum % Area |
|---|---|---|---|---|
| Black River Watershed | 1963 | 83 | <0.01 | 26.50 |
| | 1978 | 80 | <0.01 | 26.53 |
| | 1992 | 86 | <0.01 | 23.87 |
| 500 meter nest site buffer | 1962-1964 | 19 | 0.19 | 57.78 |
| | 1977-1979 | 8 | 0.76 | 57.28 |
| | 1991-1993 | 20 | 0.17 | 61.74 |

Table 2. Number of nests in Black River Watershed, Michigan with land cover class occurring within 500 meters of nest site in 1963, 1978 and 1992.

| Level 4 MIRIS code | Description | No. of nests 1963 (n = 8) | 1978 (n = 3) | 1992 (n = 10) |
|---|---|---|---|---|
| 1130 | Residential | 1 | | 2 |
| 1730 | Extractive - wells | | | 4 |
| 3100 | Non-forested - herbaceous | 3 | 1 | 2 |
| 3200 | Shrub | 3 | | 5 |
| 4110 | Northern hardwood | 3 | | |
| 4111 | Sugar maple predominant | 1 | | |
| 4130 | Aspen, white birch and assoc. | 8 | 3 | 6 |
| 4132 | Bigtooth aspen predominant | | | 2 |
| 4143 | Lowland hardwood - soft maple predominant | 3 | | 2 |
| 4146 | Aspen predominant | 3 | 2 | 5 |
| 4149 | Other lowland hardwood | | | 1 |
| 4210 | Coniferous - pine | | | 1 |
| 4212 | Red pine predominant | 4 | | |
| 4213 | Jack pine predominant | 1 | 1 | 5 |
| 4221 | Upland conifer - white spruce predominant | 1 | | |
| 4230 | Lowland conifers | 5 | 2 | 4 |
| 4231 | Cedar predominant | 1 | | |
| 4232 | Black spruce predominant | 1 | | |
| 4900 | Other forested | | | 1 |
| 5100 | Stream | 6 | 2 | 7 |
| 5200 | Lake | 4 | 2 | 4 |
| 5300 | Reservoir | | | 1 |
| 6110 | Forested wetland - wooded | 2 | | 4 |
| 6120 | Scrub, shrub | 5 | 2 | 6 |
| 6210 | Non-forested wetland - aquatic bed | 3 | | 2 |
| 6220 | Emergent | | | 2 |

Table 3. Land cover class as percent of total Black River Watershed, Michigan area and percent of combined bald eagle nest site buffer areas. Only classes present in nests or occurring >2.0% in at least one time step are shown.

| | | Black River Watershed | | | 500 meter nest site buffer | | |
|---|---|---|---|---|---|---|---|
| MIRIS Code | Description | 1963 | 1978 | 1992 | 1962-1964 | 1977-1979 | 1991-1993 |
| 1130 | Residential | 0.96 | 1.01 | 1.39 | 0.93 | 0.00 | 8.21 |
| 2100 | Cropland | 6.83 | 6.17 | 6.30 | 0.00 | 0.00 | 0.00 |
| 3100 | Non-forested - herbaceous | 5.96 | 6.40 | 6.82 | 2.51 | 5.81 | 2.09 |
| 3200 | Shrub | 2.67 | 2.68 | 6.78 | 2.42 | 0.00 | 4.23 |
| 4110 | Northern hardwood | 7.61 | 7.61 | 7.07 | 4.58 | 0.00 | 0.00 |
| 4111 | Sugar maple predominant | 3.35 | 3.33 | 3.15 | 0.02 | 0.00 | 0.00 |
| 4121 | Red oak predominant | 2.41 | 2.41 | 2.30 | 0.00 | 0.00 | 0.00 |
| 4130 | Aspen, white birch and assoc. | 26.50 | 26.53 | 23.87 | 19.91 | 37.22 | 6.76 |
| 4132 | Bigtooth aspen predominant | 2.01 | 2.00 | 1.70 | 0.00 | 0.00 | 3.04 |
| 4140 | Lowland hardwoods | 2.15 | 2.15 | 2.01 | 0.00 | 0.00 | 0.00 |
| 4143 | Soft maple predominant | 1.33 | 1.34 | 1.23 | 11.57 | 0.00 | 7.03 |
| 4146 | Aspen predominant | 3.71 | 3.69 | 3.44 | 6.01 | 18.81 | 7.07 |
| 4210 | Coniferous - pine | 3.42 | 3.44 | 3.25 | 0.00 | 0.00 | 1.59 |
| 4212 | Red pine predominant | 3.78 | 3.85 | 3.59 | 2.79 | 0.00 | 0.00 |
| 4213 | Jack pine predominant | 6.14 | 6.15 | 5.63 | 3.16 | 8.43 | 15.45 |
| 4230 | Lowland conifers | 8.70 | 9.06 | 8.85 | 5.47 | 11.38 | 6.40 |
| 4231 | Cedar predominant | 1.41 | 1.41 | 1.38 | 6.02 | 0.00 | 0.00 |
| 5200 | Lake | 3.35 | 3.34 | 3.35 | 18.18 | 16.37 | 15.77 |
| 5300 | Reservoir | 0.14 | 0.28 | 0.28 | 0.00 | 0.00 | 2.07 |
| 6110 | Forested wetland - wooded | 0.62 | 0.38 | 0.38 | 0.86 | 0.00 | 4.02 |
| 6120 | Scrub, shrub | 2.78 | 2.70 | 2.72 | 12.43 | 1.44 | 4.03 |
| 6220 | Non-forested wetland - emergent | 0.54 | 0.50 | 0.55 | 0.00 | 0.00 | 8.69 |

Table 4. Means of percent land cover by cover class and change over time for Black River Watershed bald eagle nests within 3 time steps.

| MIRIS Class | | | | Time Step | | | |
|---|---|---|---|---|---|---|---|
| Level 1 | Level 2 | Level 3 | Level 4 | 1962-1964 | 1977-1979 | 1991-1993 | P |
| Urban | Residential | — | — | 0.9 | 0.0 | 8.2 | 0.67 |
| " | Extractive | Wells | — | 0.0 | 0.0 | 0.3 | 0.08 |
| Non-forested | Herbaceous | — | — | 2.9 | 5.8 | 2.1 | 0.55 |
| " | Shrub | — | — | 2.5 | 0.0 | 4.2 | 0.34 |
| Forested | Broadleaved | Northern hardwood | No predominant | 6.3 | 0.0 | 0.0 | 0.07 |
| " | " | " | Sugar Maple | <0.1 | 0.0 | 0.0 | 0.44 |
| " | " | Aspen, White Birch | No predominant | 19.8 | 37.2 | 6.8 | 0.02 |
| " | " | and Associates | Bigtooth Aspen | 0.0 | 0.0 | 3.0 | 0.32 |
| " | " | Lowland hardwood | Soft Maple | 11.2 | 0.0 | 7.0 | 0.42 |
| " | " | " | Aspen | 4.3 | 18.8 | 7.1 | 0.28 |
| " | " | " | Other | 0.0 | 0.0 | 0.1 | 0.58 |
| " | Coniferous | Pine | No predominant | 0.0 | 0.0 | 1.6 | 0.58 |
| " | " | " | Red Pine | 2.8 | 0.0 | 0.0 | 0.02 |
| " | " | " | Jack Pine | 0.0 | 8.4 | 15.5 | 0.08 |
| " | " | Other upland conifers | White Spruce | 0.9 | 0.0 | 0.0 | 0.44 |
| " | " | Lowland conifer | No predominant | 5.5 | 11.4 | 6.4 | 0.47 |
| " | " | " | Cedar | 9.2 | 0.0 | 0.0 | 0.18 |
| " | " | " | Black Spruce | <0.1 | 0.0 | 0.0 | 0.44 |
| " | Other | — | — | 0.0 | 0.0 | 1.6 | 0.58 |
| Water | Stream | — | — | 1.1 | 0.5 | 0.7 | 0.50 |
| " | Lake | — | — | 18.2 | 16.4 | 15.8 | 0.97 |
| " | Reservoir | — | — | 0.0 | 0.0 | 2.1 | 0.58 |
| Wetlands | Forested | Wooded | — | 0.9 | 0.0 | 4.0 | 0.42 |
| " | " | Scrub, shrub | — | 12.4 | 1.4 | 4.0 | 0.41 |
| " | Nonforested | Aquatic bed | — | 1.1 | 0.0 | 0.9 | 0.42 |
| " | " | Emergent | — | 0.0 | 0.0 | 8.7 | 0.32 |

Table 5. Mean percent land cover for Black River Watershed, Michigan bald eagle nest areas within activity and production groups.

| MIRIS Class | | | | Activity | | | Production | | |
|---|---|---|---|---|---|---|---|---|---|
| Level 1 | Level 2 | Level 3 | Level 4 | A* | I | P | P+ | F | P |
| Urban | Residential | — | — | 5.6 | 6.6 | 0.45 | 16.7 | 0.0 | 0.30 |
| " | Extractive | Wells | — | 0.2 | 0.2 | 0.71 | 0.5 | 0.0 | 0.08 |
| Non-forested | Herbaceous | — | — | 3.4 | 1.9 | 0.94 | 4.2 | 3.5 | 1.00 |
| " | Shrub | — | — | 2.3 | 1.9 | 0.74 | 3.1 | 0.4 | 0.70 |
| Forested | Broadleaved | Northern hardwood | No predominant | 1.1 | 3.0 | 0.77 | —[a] | — | |
| " | " | Aspen, White Birch and Associates | No predominant | 14.5 | 18.8 | 0.46 | 9.3 | 20.4 | 0.76 |
| " | " | | Bigtooth Aspen | 1.5 | 2.8 | 0.77 | 0.0 | 2.7 | 0.61 |
| " | " | Lowland hardwood | Soft Maple | 13.3 | 2.3 | 0.74 | 20.6 | 0.0 | 0.30 |
| " | " | " | Aspen | 7.0 | 10.9 | 0.61 | 6.9 | 5.4 | 0.49 |
| " | " | " | Other | 0.1 | 0.0 | 0.50 | 0.3 | 0.0 | 0.30 |
| " | Coniferous | Pine | No predominant | 1.8 | 0.0 | 0.50 | 0.0 | 3.2 | 0.61 |
| " | " | " | Red Pine | 0.1 | 2.8 | 0.77 | 0.0 | 0.2 | 0.61 |
| " | " | " | Jack Pine | 11.0 | 4.7 | 0.60 | 8.4 | 14.7 | 0.73 |
| " | " | Other upland conifers | White Spruce | 0.0 | 1.1 | 0.28 | — | — | |
| " | " | Lowland conifer | No predominant | 2.7 | 7.6 | 0.35 | 0.6 | 4.5 | 1.00 |
| Water | Stream | — | — | 1.0 | 0.6 | 0.91 | 1.1 | 0.5 | 1.00 |
| " | Lake | — | — | 19.0 | 22.5 | 0.72 | 17.0 | 24.0 | 1.00 |
| " | Reservoir | — | — | 2.3 | 0.0 | 0.50 | 0.0 | 4.1 | 0.61 |
| Wetlands | Forested | Wooded | — | 4.0 | 0.2 | 0.41 | 10.4 | 0.3 | 0.70 |
| " | " | Scrub, shrub | — | 3.7 | 4.0 | 0.49 | 0.7 | 6.1 | 0.42 |
| " | Nonforested | Aquatic bed | — | 1.0 | 0.1 | 0.74 | 0.0 | 1.9 | 0.33 |
| " | " | Emergent | — | 4.4 | 7.8 | 0.77 | 0.0 | 8.0 | 0.61 |

* Activity groups: A – active, I – inactive

+ Production groups: P – productive, F – Failed

[a] Class not present in active nests with known outcomes

Resource selection analysis indicated preferred land cover classes for nest areas including urban, lowland hardwood (soft maple and aspen), lowland conifer (cedar), water and wetland. A preference for upland jack pine was indicated but not significant. Aspen / white birch (bigtooth aspen) and upland conifer (white spruce) where neither preferred nor avoided, and all other classes were avoided ($P < 0.10$, Table 6).

## DISCUSSION

In general, land cover classes associated with bald eagle nest sites in the BRW are consistent with general habitat preferences of forested areas near (< 2 km) large bodies of water (Buehler 2000). Bowerman (1993) described Michigan bald eagle nesting habitat but only for nests associated with the Great Lakes and the focus was on microhabitat variables (e.g., availability of nest and perch trees, type and proximity of disturbance, amount of forested area). Another study currently in review (K. Eisenreich, Clemson University, personal communication) used GIS methods and land use / land cover data for the entire state. However, the land cover data was from the U.S. Environmental Protection Agency's 1983 coverage in the Anderson classification system. The coverage was developed from larger scale 1:250,000 quadrangles and only broad cover classifications such as agriculture, forested and wetland were used. Using such broad classes does not identify more specific habitat associations characteristic of the Great Lakes region. This is the first time bald eagle nest habitat has been described for Michigan using land cover data at a finer resolution (1:24,000 scale).

Land cover classes that were identified either as preferred (Table 6) or consistently present through time (Table 4) tend to be forest classes that are associated

Table 6. Habitat selection based on land cover composition within 500 meters of bald eagle nest locations in the Black River Watershed, Michigan represented by confidence intervals of proportion used compared to proportion available.

| MIRIS Class | | | Lower CL | Upper CL | Proportion Available | Resource Selection | P |
|---|---|---|---|---|---|---|---|
| Level 1 & 2 | Level 3 | Level 4 | | | | | |
| Urban (residential, extractive – wells) | | | 0.031 | 0.058 | 0.013 | Prefer | 0.0001 |
| Agriculture | | | 0.000 | 0.000 | 0.065 | Avoid | 0.0001 |
| Non-forested (herbaceous, shrubland) | | | 0.043 | 0.075 | 0.111 | Avoid | 0.0010 |
| Forested broadleaved | Northern hardwood | No predominant | 0.014 | 0.034 | 0.074 | Avoid | 0.0001 |
| " | " | Sugar Maple | 0.000 | 0.001 | 0.033 | Avoid | 0.0001 |
| " | Oak/hickory | Red Oak | 0.000 | 0.000 | 0.024 | Avoid | 0.0010 |
| " | Aspen, white birch | No predominant | 0.137 | 0.185 | 0.253 | Avoid | 0.0001 |
| " | and associates | Bigtooth Aspen | 0.007 | 0.022 | 0.019 | | |
| " | Lowland hardwood | No predominant | 0.000 | 0.000 | 0.021 | Avoid | 0.0500 |
| " | " | Soft Maple | 0.058 | 0.094 | 0.013 | Prefer | 0.0001 |
| " | " | Aspen | 0.059 | 0.095 | 0.036 | Prefer | 0.0001 |
| " | " | Other | 0.000 | 0.002 | 0.000 | | |
| Forested coniferous | Pine | No predominant | 0.002 | 0.013 | 0.033 | Avoid | 0.0500 |
| " | " | Red Pine | 0.004 | 0.017 | 0.037 | Avoid | 0.0500 |
| " | " | Jack Pine | 0.067 | 0.104 | 0.059 | Prefer | N.S.* |
| " | Other upland conifers | White Spruce | 0.000 | 0.007 | 0.002 | | |
| " | Lowland conifer | No predominant | 0.051 | 0.084 | 0.088 | Avoid | N.S. |
| " | " | Cedar | 0.023 | 0.047 | 0.014 | Prefer | 0.0001 |
| Water (lakes, streams, reservoirs) | | | 0.160 | 0.212 | 0.040 | Prefer | 0.0001 |
| Wetlands (aquatic bed, emergent, scrub/shrub, forested) | | | 0.118 | 0.164 | 0.039 | Prefer | 0.0001 |

* Selection indicated but not significant

with lakes and streams in Michigan (lowland hardwoods, lowland conifers and wetlands). Some surprising results were noted in classes representing factors of particular importance (i.e., water (Buehler 1995, Swenson et al. 1986), urban (residential and industrial; Mathisen 1968, Grubb et al. 1992, Grubb and Bowerman 1997)). Residential areas, while occurring at low levels in all categories, increased in nest areas more so than in the watershed from 1978 to 1992, leading to the urban class being designated as preferred (Table 6). This would seem to indicate increasing tolerance for disturbance and would be counter-intuitive. More likely, rather than a true change in disturbance tolerance, this is probably a statistical artifact due to increased development and land conversion during the same time that the number of nesting areas increased.

Though changes in water cover classes over time were not significant, an unexpected trend was noticed. The percentage of lakes, and reservoirs to a lesser extent, showed an overall decline in nest areas over time. While water was a preferred cover class (Table 6) and consistently comprised a greater percentage of nesting areas than BRW area through time, the percentage of water in BRW area did not change (Table 3). This could indicate a reduction of nests located on inland lakes, possibly due to increasing development and recreation on lakeshores. However, this could simply be due to the increase in the bald eagle nesting population. While eagle nesting habitat over the entire state was not saturated by 1992, the number of nesting pairs had nearly tripled since 1978. By the last year of this analysis, nest areas near water in the BRW may have all been occupied, forcing newer pairs to establish nests farther away from lake and river shorelines.

Other than the slight discrepancies in what would be expected with urban and water classes, most of the preferred land cover classes (water, wetland, lowland hardwood and lowland conifer; Table 6) are consistent with what is generally considered suitable bald eagle nesting habitat. However, it cannot be assumed that eagles are selecting nest areas based on these habitat variables alone. It is more likely that their tendency to nest near water plays a greater role and the preferred land cover classes indicated are simply characteristic of lowland areas surrounding water bodies in Michigan.

Occurrence of jack pine cover steadily increased in nest areas over time, but in the BRW it remained unchanged from 1963 to 1978 and declined slightly from 1978 to 1992. Even with this increase, 1992 was the only time period in which it occurred at a greater percentage in the nest areas than in the watershed (Table 4). While a preference for upland jack pine was indicated, this class occurred at a low percentage (~ 6 %) of nest area composition, and probably does not have a significant relationship to nesting biology (Table 6). This is more likely caused by both the increased number of breeding pairs and increased lake shore development that would lead to nests being established farther from water bodies, increasing upland cover classes surrounding nests. As such, it could be an indicator (or consequence) of the pattern noted in urban and water classes. Cover classes that were avoided (Table 6) are also consistent with general nesting area preferences in that avoided classes tend to be upland classes (greater distance to water) or agriculture and non-forested (lack of suitable nest trees).

All wetland cover classes also fluctuated over time in nest areas, while remaining unchanged in the watershed (Table 3). This is probably an effect of the small sample size for each time period and the relatively low occurrence of these classes in nest area composition which would exaggerate the fluctuations. When all wetland classes were grouped and all nests used for resource selection analysis, wetlands were generally preferred. Again, this is most likely an effect of their proximity to large bodies of water rather than an active selection for the wetlands specifically.

Classes showing a significant temporal change (extractive – wells; northern hardwoods; aspen, white birch and associates; red pine; jack pine) generally occurred at fairly low levels during all time periods and may not indicate a true change in nest area land cover composition. Cover classes comprising the greatest proportion of combined nest areas (aspen / white birch and associates, and soft maple and aspen predominated lowland hardwoods) tended to vary in the same way but to a greater extent than in the BRW (Table 3). This generally involved an increase from 1963 to 1978, followed by a decrease from 1978 to 1992, and is most likely a reflection of regional land management rather than changes in nest use. However, nest tree selection could be more of a factor in this pattern as surrounding nest area. Forest management practices may have led to a greater abundance of large, mature aspen and maple in the late 1970's, while harvest and senescence could have reduced the availability of these trees by the 1990's. Rutledge (2001) found that aspen / white birch had the greatest total area of land conversion, and lowland hardwoods had the third greatest area converted within the BRW. The amount of these cover classes in the watershed would not have changed much in total area, as regenerating stands would be included in land cover descriptions. However, the trees would not be large enough yet to support an eagle nest, and could account for the greater decrease in nesting area aspen / maple cover classes in 1992.

The lack of differences between active and inactive nests has two possible causes.

First, nest establishment and use is probably based more on a smaller scale of habitat variables and proximity to open water early in the season (Buehler 2000, Swenson et al. 1986). If surrounding land cover has an affect on activity (i.e., prone to disturbance, lack of adequate cover) it may not be realized until later in the season after a nesting attempt has been made. These cases are still considered active though they may have failed. Secondly, because breeding pairs of bald eagles maintain and may reuse alternate nests, activity and inactivity are not mutually exclusive within breeding areas. This would have affected statistical analysis since the two categories are not independent samples.

There were also no differences in land cover between productive and failed nests other than in the extractive – wells cover class. This class was higher in productive nests and showed a significant increase over time, but probably has no effect since it only occurred at extremely low levels (< 1.0%). Some differences were expected as the presence of some classes and resulting edge effects could influence foraging quality, cover, and likelihood of predation or disturbance affects. The small sample size certainly affected the results of this analysis as well, so the results of production comparisons were considered inconclusive.

## LIMITATIONS AND MANAGEMENT IMPLICATIONS

Results of this analysis do indicate some obvious patterns, but these should be considered cautiously due to limitations of the analysis. While the land cover time series allowed examination of temporal changes, the geographic extent is limiting. The combination of a small area (relative to bald eagle habitat use) and the reduced eagle population led to very small sample sizes. This in turn reduces the power of statistical analysis. This is somewhat alleviated by the quality of the land cover data. The land cover database was developed specifically to study changes over time in this region of the state (Rutledge 2001). Therefore, the land cover associated with eagle nests in the BRW can be considered reliable even if the lack of nest sites does lend itself to hypothesis testing.

Resource selection analysis should also be considered carefully. A problem typically encountered with compositional data is that proportional composition is not independent. An increase in one cover class will lead to a decrease in another cover class. For this reason, a preference in one class will inevitably lead to an apparent avoidance of another class (Aebischer et al. 1993), so there were some concerns in using the Neu method (Neu et al. 1974). This constraint was ultimately considered acceptable though following a comparison of selection analysis methods conducted by McClean et al. (1998). The authors found that the Neu method was the only method that identified selection patterns consistent with known requirements and did so across several spatial scales.

In spite of these limitations, there are trends that may be useful. Although land cover among nests is highly variable, the overall habitat preferences do not seem to have truly changed over time. Land cover classes that seem to be preferred consistently comprise the greatest proportion of nest areas but are typically those that have also been the most intensively managed or subject to conversion (e.g., jack pine, aspen, wetlands). Because of this, the temporal changes in the amount of those land cover classes should be interpreted as being due to land management practices rather than changing habitat preference of bald eagle breeding pairs. This implies that breeding pairs are not necessarily becoming more tolerant of less suitable areas. Some biologists have noted that nesting eagles may be more tolerant of human activities than once believed (D. Best, personal communication).

Michigan's breeding eagle population has increased very rapidly, clouding the line between intolerance or simply taking what is available. Timing and type of disturbance may play a greater role in nest success than just the presence of human activity. A nest is less likely to be abandoned later in the season, but pairs may be more likely to accept some disturbance if it is already there when they begin nesting (S. Postupalsky, personal communication). This does not necessarily mean they will use the same nest again in following years if a more suitable area is available. Managers should keep in mind that as the eagle population continues to expand, the availability of optimal breeding areas will decrease, and as breeding pairs begin to settle in sub-optimal areas, they may experience lower reproductive rates. If the population experiences another serious decline caused by increased mortality (e.g., disease factors, environmental contaminants) optimal habitat may play an important role in maintaining reproductive success.

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CHAPTER 3

# LAND USE / LAND COVER ASSOCIATED WITH BALD EAGLE BREEDING AREAS IN THE NORTHERN LOWER PENINSULA OF MICHIGAN

## INTRODUCTION

Many studies have been conducted on the bald eagle in the United States. These studies cover a variety of subjects including contaminant and human disturbance effects on production, habitat use by non-breeding birds (sub-adults and wintering birds), foraging habits and population dynamics. Nest habitat characteristics seem to have not received as much attention as these other factors, even though nest sites are integral for reproduction and their protection and management are mandated by the ESA. In over 300 references used by Buehler (2000), approximately 20 focused specifically on nest site selection and nesting habitat. Of these, nesting habitat has been described primarily in the Pacific Northwest (Anthony and Isaacs 1989, Garrett et al. 1993), Northeastern U.S. (Andrew and Mosher 1982, Livingston et al. 1990) and Southeastern U.S. (Wood et al. 1989, Hardesty and Collopy 1990, Buehler 1995).

Nesting habitat studies also concentrate on variables associated with individual nests where breeding activity occurs. This is certainly legitimate and even necessary when most data used in these analyses are collected over a period of 2 – 4 years. Over time though, bald eagle breeding pairs build up clusters of nests, all of which may be maintained and reused. These clusters are referred to as breeding areas (BAs) that are by definition "the local area associated with one territorial pair of eagles and containing one or more nest structures" (Postupalsky 1983). This "local area" may contain habitat variables beyond an individual nest site that may still factor into nest habitat suitability. Furthermore, some state's monitoring programs track production by nest, but also maintain information on which nests are associated to form BAs (Michigan, New York, Ohio; D. Best, personal communication).

Because eagle pairs will alternate nests over time, some types of data may also be better analyzed on the level of BA (contaminants, productivity; D. Best, personal communication), especially when analysis is done over several years or several different time periods. Truly linking these variables with habitat components of the same spatial extent is typically not done, however, for two reasons. First, a fairly long-term dataset for these variables is required to take into account the area associated with alternate nests that are built over time. Second, there are no real geographic boundaries for BAs since only an active nest is actively defended in terms of what is commonly thought of as a "territory".

Some bald eagle research in the Great Lakes region, particularly Michigan, have been conducted in relation to BAs rather than nests, but still have not been linked to broader scale habitat variables such as land cover data. Furthermore, these analyses have concentrated on contaminant effects (Bowerman 1993; Bowerman et al. 1994, 1998, 2000), response to human disturbance (Mathisen 1968, Grubb et al. 1992, Grubb and Bowerman 1997) and microhabitat variables such as nest tree characteristics (Grewe 1980, Mathisen 1983, Bowerman 1993).

In 1961, an annual statewide monitoring program was initiated in Michigan to address concerns of a dramatically declining eagle population. This program currently provides over 40 years of information on eagle nest location and production. This data set, coupled with the increasing availability of digital spatial data, provides an excellent resource in determining both spatial and temporal patterns of land use / land cover associated with bald eagle nesting habitat and productivity, and makes analyses possible for a large geographic area. This study is an opportunity to analyze nesting habitat during two time periods on a BA level. Specific objectives were to develop a method of delineating bald eagle BAs and use this to determine patterns in land cover associated with habitat preferences in BAs, temporal changes in BA land cover and differences in land cover between active and inactive, and productive and failed BAs on a regional scale.

## STUDY AREA

Because standard, annual data collection on bald eagles did not begin until after the species had become restricted to northern Michigan, the majority of breeding locations are distributed throughout the NLP and UP. To conduct analysis on this broad a spatial scale and include a temporal component, regional land cover data was needed for more than one time period. The availability of existing GIS coverages of this nature focused the study on the NLP (Figure 4). The most common land cover types in this region are cropland, northern hardwood forests and aspen / white birch forests, which together comprise approximately 45% of the region's land cover.

## METHODS

### *Data Preparation and Breeding Area Delineation*

Regional land use / land cover data for two time periods was obtained from the MDNR Wildlife Division. The 1978 dataset is a 1:24,000 scale statewide coverage

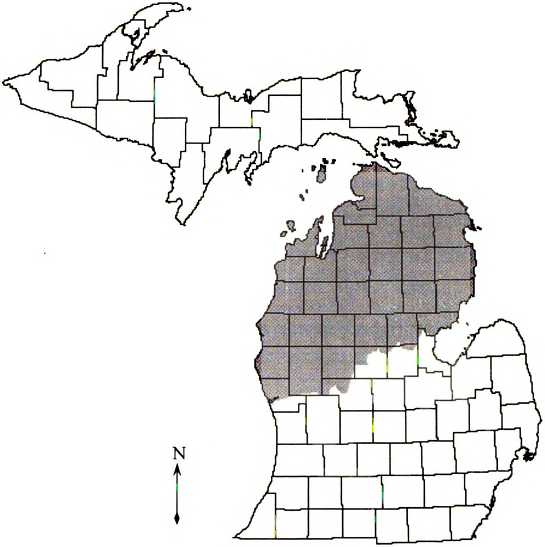


Fig. 4. Study area for bald eagle breeding areas in the northern lower peninsula of Michigan.

developed from color-infrared and black-and-white aerial photography in the MIRIS classification scheme. The 1993 coverage is for the NLP in the Gap Analysis Project (GAP) classification scheme. This dataset was obtained as a grid developed from 30 m LandSat satellite imagery. The grid was converted to a polygon coverage using Arc / Info, and a crosswalk was developed between the land classification systems to convert MIRIS land cover codes to equivalent GAP land cover codes.

To analyze land cover associated with BAs rather than individual nests, BA boundaries had to be established. However, there are several difficulties in determining this area. Due to the dynamic nature of nest building and use within a BA from year to year, there are no true spatial boundaries for an entire BA. Only one nest is used per year but the number of alternate nests existing and which one is used in any given year can be highly variable. All alternate nests associated with a breeding pair of eagles are unavailable for use by another pair, but it is the active nest that will be the most actively defended. Inactive nests within active BAs may still be used for perching.

Determining a spatial reference associated with BAs on which to construct a buffer also posed problems. If only nests existing in one year are used, then variability in nest use is not taken into account, and some established BAs might not have any nest structures present in that year to provide a spatial reference. To overcome this, nests existing at any time within a 5-year period centered on the land cover year (1976 – 1980 and 1991 – 1995) were used to establish spatial references for BAs. ArcView 3.2 was used to clip the geographic extent of the NLP from a statewide digital point file of all nest locations (Appendix I). Production records were used to limit the selected nests to those existing at some time within the two 5-year periods. Because the number of nests varies among BAs, simply using existing nests to establish a preliminary boundary (i.e., minimum convex polygon method) for buffering would cause inconsistencies in final BA area. To maintain consistency in the area of land cover analyzed, each BA was buffered around a single point. To avoid centering the buffer on a single nest when multiple nests may be used over a 5-year period, a weighted center for each BA was used.

The number of years each nest existed and the number of years each was active within the corresponding time period were calculated. An activity weight was calculated based on the number of years a nest existed out of 5 years possible and the number of years a nest was active for the time it existed:

Weight = (# years existing / 5) + (# years active / # years existing)

Using this calculation alone led to instances of nests that were present but inactive all 5 years receiving a greater weight than nests that were active but only present for 1 or 2 years. To ensure that completely inactive nests never received a greater weight than that of active nests, a correction factor was added to nests that were inactive for the entire time they were present. Since no references could be found regarding time allocation between alternate nests, a correction factor of 0.5 was chosen to ensure that completely inactive nests were weighted less than any active nests. The initial weights of these inactive nests were essentially reduced by half.

Weight factors were calculated for the selected nests and added to the attribute table. The ArcView extension Weighted Mean of Points v 1.1 (Jenness 2000) was used to determine a weighted center (activity center) of each BA. Because there is no established size for BAs, the activity centers were buffered with a circular buffer of 5 km radius (Figure 5). This distance would likely include all alternate nests as well as

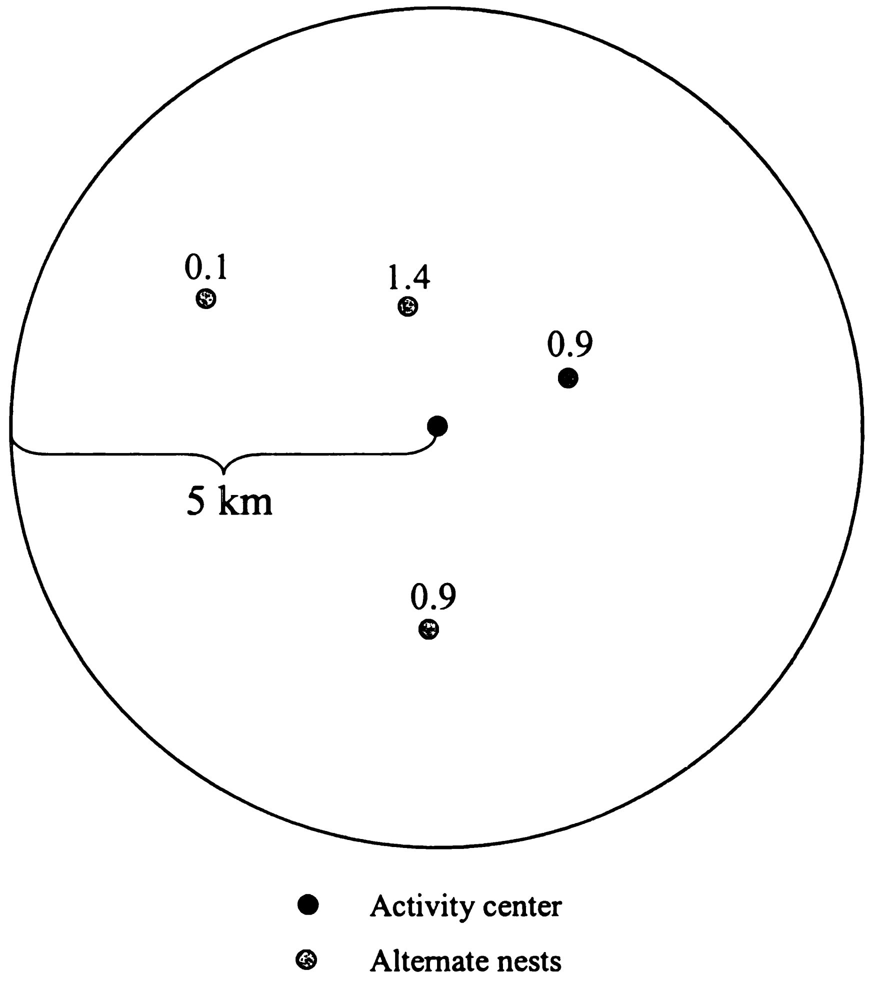


Fig. 5. Bald eagle breeding buffer showing alternate nests, nest activity weights (# above nests), activity center and buffer boundary.

potential foraging area where land cover may also be an important factor. It has also been noted that some eagles in Michigan have been seen foraging up to 8 km from the nearest nest (W. Bowerman, Clemson University, personal communication), and Swenson et al. (1986) found that a characteristic of BAs in the Yellowstone ecosystem was the presence of open water within 5 km. The final BA coverage consisted of 5 km BA boundaries centered on activity centers.

*GIS and Statistical Analysis*

Land cover was summarized by 32 GAP land cover classes for the entire study area, and percent total area was calculated for each class for each year (1978 and 1993). BA land cover was determined by using Arc / Info (ESRI, Redlands, California) to intersect each 5 km BA buffer coverage with its respective year's land use / cover coverage. The resulting BA land cover was summarized by GAP land cover class and percent area of each class was calculated for each BA. Several classes were grouped for analysis using BAs only (temporal, activity and production) to allow better conversion of MIRIS classes to GAP classes. This involved grouping "lowland evergreen needle-leaved shrub" with "shrubland", and "lowland broad-leaved deciduous shrub" and "lowland broad-leaved evergreen shrub" with "other lowland shrub", resulting in 29 GAP classes (Table 7). Two GAP classes (northern hardwood/conifer and mixed lowland conifer/hardwood) had no equivalent MIRIS classes, so the 1978 time period had only 27 GAP classes. For analyses, a value of zero was added to these two classes for all 1978 BAs. Because some BA buffer boundaries were cut off by the Great Lakes shoreline, the difference between the area of these BAs and the area of a full 5 km radius buffer was calculated and added to the water cover class.

Table 7. Grouped GAP land cover classes and number of bald eagle breeding areas (BAs) in the northern lower peninsula of Michigan with land cover class occurring within BA.

| GAP class description | No. of BAs 1978 (n = 42) | 1992 (n = 107) |
|---|---|---|
| High intensity urban | 41 | 105 |
| Low intensity urban | 21 | 29 |
| Extractive | 30 | 76 |
| Agricultural crops | 33 | 107 |
| Orchard/vineyard | 11 | 10 |
| Herbaceous openland | 42 | 107 |
| Shrubland | 42 | 104 |
| Other broad-leaved deciduous forest | 3 | 48 |
| Northern hardwood | 33 | 107 |
| Northern hardwood/ conifer * | — | 80 |
| Aspen/birch | 39 | 107 |
| Oak | 36 | 99 |
| Oak/jack pine | 1 | 12 |
| Other coniferous forest | 27 | 82 |
| White pine | 20 | 42 |
| Red pine | 31 | 106 |
| Upland jack pine | 20 | 98 |
| Cedar Spruce Fir | 20 | 23 |
| Emergent wetland/wet meadow | 42 | 106 |
| Other lowland shrub | 42 | 104 |
| Other forested wetland | 29 | 61 |
| Mixed lowland hardwood | 42 | 60 |
| Lowland jack pine | 26 | 20 |
| Black spruce | 2 | 55 |
| Northern white cedar | 1 | 50 |
| Mixed lowland conifer/hardwood * | — | 103 |
| Barren land | 6 | 38 |
| Water | 42 | 107 |
| Urban grassland | 29 | 80 |

* No MIRIS equivalent

BA land cover was grouped by time step and each of the 29 resulting land cover classes were tested using a Mann-Whitney U ($\alpha = 0.10$) to detect significant temporal changes in BA land cover. BAs existing in multiple time steps were treated as separate occurrences since land cover may have changed over time, and this analysis is based on use of alternate nests rather than their establishment. To determine if BA land cover had any significant affect on activity or production, activity and production categories were assigned to BAs. Activity and production categories were based on whether each BA was active (A) or inactive (I) in 1978 and / or 1993, and active BAs were classified as productive (P) or failed (F). Because activity and production are variable across years for individual nests, BAs established after the year of land cover data were not used. For example, a BA established in 1979 would only be included for its activity in the 1993 time period. A Mann-Whitney U ($\alpha = 0.10$) was used to test each of the 29 land cover classes for differences within activity and production categories.

Preference or avoidance in BA land cover was analyzed using Resource Selection Analysis Software (Leban 1999). Because difficulties converting MIRIS classes to GAP classes led to questionable results in temporal and activity analyses, only 1993 BA land cover composition was used. All 32 GAP classes were used without grouping. Land cover composition of the entire NLP study area was designated as available resource. The data matrix was prepared by pairing each BA composition (used resource) with NLP composition (available resource). This was entered into the software and analyzed using the Neu method (Neu et al. 1974; $\alpha = 0.10$), which combines the use of chi-square goodness-of-fit analysis and construction of Bonferroni simultaneous confidence intervals to represent actual proportion of resource used. The result is preference, avoidance, or neither for each cover class based on where the predicted use value falls in reference to the confidence interval. For instance, if the lower confidence limit of used resource is greater than the predicted value, that class is considered preferred. Great Lakes shoreline BAs were used without adding Great Lakes composition, since establishing a boundary beyond the Great Lakes shoreline to delineate as associated available resource would be somewhat arbitrary.

RESULTS

One-hundred forty-nine BAs existed in the NLP during the given time periods. All BAs were used for temporal analysis, 42 in 1976-1980 and 107 in 1991-1995. Only 141 BAs existed in the same years as the land cover data, leaving 110 active and 31 inactive BAs for activity comparisons. For production comparisons, 64 BAs were productive and 46 failed. After conversion of MIRIS land cover classes to GAP classes, 30 GAP classes occurred in 1978 and all 32 classes occurred within the NLP and BAs in 1993. Of all cover classes occurring within the total area of BAs in either time step, most were present in approximately two-thirds of BAs. Water, herbaceous openland, shrubland, emergent/wet meadow, forested wetland and mixed lowland hardwood occurred in all BAs in 1978. By 1993, the classes occurring in all BAs were water, aspen/birch, northern hardwood, herbaceous openland and agricultural crops (Table 7).

Aspen / birch, northern hardwoods and agriculture occur in the greatest percentage across the NLP, while aspen / birch and oak are greatest among the BAs. Seventeen cover classes occurred at >2% of total BA area in at least one time period (Table 8). All classes fluctuated over time in both the NLP and BAs. For most classes,

Table 8. Percent land cover composition of study area and combined area of bald eagle breeding areas (BA) in the northern lower peninsula (NLP) of Michigan.

| | NLP | | BA | |
|---|---|---|---|---|
| GAP code description | 1978 | 1993 | 1978 | 1993 |
| High intensity urban | 2.83 | 3.45 | 2.64 | 2.62 |
| Agricultural crops | 14.01 | 18.12 | 2.93 | 8.18 |
| Herbaceous openland | 7.60 | 6.46 | 3.89 | 5.82 |
| Shrubland | 4.44 | 1.67 | 3.27 | 1.72 |
| Northern hardwood | 14.11 | 17.44 | 5.91 | 11.34 |
| Aspen/Birch | 14.71 | 11.87 | 17.48 | 14.05 |
| Oak | 8.94 | 3.86 | 15.70 | 5.87 |
| Other coniferous forest | 2.71 | 1.25 | 3.91 | 1.61 |
| White pine | 2.98 | 0.05 | 6.10 | 0.05 |
| Red pine | 5.69 | 4.26 | 6.48 | 4.70 |
| Upland jack pine | 1.54 | 6.15 | 1.98 | 9.40 |
| Emergent wetland | 0.79 | 1.44 | 1.57 | 2.36 |
| Lowland shrub | 2.88 | 3.12 | 4.23 | 3.08 |
| Mixed lowland hardwood | 7.40 | 1.84 | 6.23 | 1.70 |
| Lowland jack pine | 1.91 | 0.12 | 4.10 | 0.10 |
| Mixed lowland conifer/hardwood | 0.00 | 7.95 | 0.00 | 12.03 |
| Water | 3.40 | 5.54 | 6.49 | 6.93 |
| classes <2.0% of total area | 4.06 | 5.41 | 4.14 | 5.88 |

temporal changes in BAs mimicked changes in the NLP. While most classes increased or decreased similarly over time in both the NLP and BAs, changes in BAs tended to be more extreme.

Two classes showed temporal changes in BAs that were the reverse of their change in the NLP. Herbaceous openland, while decreasing slightly in the NLP, increased in BAs, and lowland shrub decreased in BAs while increasing in the NLP (Table 8). Amount of water in combined BAs remained the same from 1978 to 1993 even though it increased in the NLP. Amount of agricultural cropland in BAs remained less than half the percent it occurred in the NLP, but the amount of increase in BAs was greater than in the NLP (Table 8). Upland jack pine also increased to a greater degree in BAs, and went from approximately equal proportions in the NLP and BAs in 1978 to 50% greater in BAs than the NLP in 1992. Oak decreased over time in both the BAs and NLP, but dropped to a greater extent in BAs. High intensity urban increased only slightly in the NLP and remained unchanged in BAs (Table 8).

Twenty-one classes showed significant ($P < 0.10$) changes over time in BAs. Of these, 11 classes increased in percent area from 1978 to 1993, and the remaining 10 decreased (Table 9). Most lowland and wetland classes were among those that decreased in area. Those that increased included upland, mixed conifer/hardwood, herbaceous openland, urban and agriculture classes. Eight classes were different between activity groups ($P < 0.10$), with mixed hardwood/conifer classes among those with greater area in active BAs. Orchard, lowland hardwood and lowland jack pine comprised a greater area of inactive BAs (Table 10). Differences between production categories occurred in red pine, black spruce and northern white cedar, which made up a greater percent area in

Table 9. Mean percent land cover by cover class within 2 time steps for bald eagle breeding areas in the northern lower peninsula of Michigan.

| | Time Step | | |
|---|---|---|---|
| GAP class description | 1976-1980 | 1991-1995 | P |
| High intensity urban | 2.64 | 2.65 | 0.91 |
| Low intensity urban | 0.26 | 0.39 | 0.04 |
| Extractive | 0.10 | 0.45 | 0.30 |
| Agricultural crops | 2.93 | 8.26 | <0.01 |
| Orchard / vineyard | 0.35 | 0.09 | 0.01 |
| Herbaceous openland | 3.89 | 5.88 | <0.01 |
| Shrubland | 3.27 | 1.73 | 0.01 |
| Other broad-leaved deciduous forest | 1.58 | 0.25 | <0.01 |
| Northern hardwood | 5.91 | 11.45 | <0.01 |
| Northern hardwood / conifer | 0.00 | 3.23 | <0.01 |
| Aspen / birch | 17.48 | 14.19 | 0.14 |
| Oak | 15.70 | 5.92 | <0.01 |
| Oak / Jack pine | 0.01 | 0.29 | 0.08 |
| Other coniferous forest | 3.91 | 1.63 | 0.15 |
| White pine | 6.10 | 0.05 | <0.01 |
| Red pine | 6.48 | 4.74 | 0.12 |
| Upland jack pine | 1.98 | 9.49 | <0.01 |
| Cedar Spruce Fir | 1.04 | 0.13 | <0.01 |
| Emergent wetland / wet meadow | 1.57 | 2.38 | 0.13 |
| Other lowland shrub | 4.23 | 3.11 | <0.01 |
| Other forested wetland | 0.55 | 0.18 | <0.01 |
| Mixed lowland hardwood | 6.23 | 1.72 | <0.01 |
| Lowland jack pine | 4.10 | 0.10 | <0.01 |
| Black spruce | 0.02 | 0.41 | <0.01 |
| Northern white cedar | 0.01 | 0.16 | <0.01 |
| Mixed lowland conifer/hardwood | 0.00 | 12.14 | <0.01 |
| Barren land | 0.02 | 0.16 | <0.01 |
| Water | 9.42 | 8.64 | 0.69 |
| Urban grassland | 0.20 | 0.19 | 0.46 |

Table 10. Mean percent land cover by cover class within activity and production groups for bald eagle breeding areas in the northern lower peninsula of Michigan.

| GAP class description | Activity | | | Production | | |
|---|---|---|---|---|---|---|
| | A* | I | P | P+ | F | P |
| High intensity urban | 2.61 | 2.79 | 0.19 | 2.77 | 2.38 | 0.19 |
| Low intensity urban | 0.41 | 0.18 | 0.89 | 0.35 | 0.49 | 0.16 |
| Extractive | 0.44 | 0.10 | 0.17 | 0.42 | 0.47 | 0.42 |
| Agricultural crops | 6.77 | 5.86 | 0.97 | 6.70 | 6.87 | 0.47 |
| Orchard / vineyard | 0.08 | 0.47 | 0.05 | 0.07 | 0.10 | 0.13 |
| Herbaceous openland | 5.46 | 4.79 | 0.47 | 5.73 | 5.08 | 0.86 |
| Shrubland | 2.07 | 2.38 | 0.42 | 1.76 | 2.49 | <0.10 |
| Other broad-leaved deciduous forest | 0.54 | 1.04 | 0.45 | 0.20 | 1.02 | 0.62 |
| Northern hardwood | 9.79 | 10.19 | 0.71 | 9.63 | 10.00 | 0.25 |
| Northern hardwood / conifer | 2.20 | 1.66 | 0.02 | 2.02 | 2.45 | 0.71 |
| Aspen / birch | 15.00 | 16.09 | 0.81 | 15.00 | 15.00 | 0.97 |
| Oak | 7.95 | 11.36 | 0.48 | 7.06 | 9.19 | 0.80 |
| Oak / jack pine | 0.14 | 0.39 | 0.31 | 0.20 | 0.06 | 0.32 |
| Other coniferous forest | 2.28 | 2.33 | 0.69 | 2.38 | 2.13 | 0.63 |
| White pine | 1.24 | 3.81 | 0.46 | 0.66 | 2.06 | 0.31 |
| Red pine | 5.56 | 3.81 | 0.26 | 6.75 | 3.90 | 0.06 |
| Upland jack pine | 8.15 | 3.67 | <0.01 | 9.75 | 5.91 | 0.19 |
| Cedar Spruce Fir | 0.41 | 0.30 | 0.62 | 0.13 | 0.79 | 0.03 |
| Emergent wetland / wet meadow | 2.31 | 1.78 | 0.80 | 2.12 | 2.57 | 0.46 |
| Other lowland shrub | 3.48 | 3.60 | 0.14 | 3.15 | 3.96 | 0.33 |
| Other forested wetland | 0.29 | 0.26 | 0.39 | 0.26 | 0.35 | 0.52 |
| Mixed lowland hardwood | 2.70 | 4.66 | 0.03 | 2.13 | 3.49 | 0.26 |
| Lowland jack pine | 1.13 | 1.89 | 0.01 | 1.32 | 0.86 | 0.43 |
| Black spruce | 0.35 | 0.12 | 0.05 | 0.47 | 0.19 | 0.05 |
| Northern white cedar | 0.15 | 0.02 | 0.05 | 0.22 | 0.05 | 0.03 |
| Mixed lowland conifer / hardwood | 9.31 | 5.88 | <0.01 | 9.46 | 9.09 | 0.32 |
| Barren land | 0.15 | 0.05 | 0.35 | 0.13 | 0.17 | 0.12 |
| Water | 8.84 | 10.34 | 0.70 | 9.00 | 8.62 | 0.34 |
| Urban grassland | 0.20 | 0.20 | 0.22 | 0.15 | 0.29 | 0.91 |

* Activity groups: A – active, I – inactive

\+ Production groups: P – productive, F – Failed productive BAs. Shrubland and cedar/spruce/fir occurred in greater percent area in failed BAs (Table 10).

Resource selection analysis resulted in 7 preferred classes including mixed northern hardwood/conifer, aspen/birch, oak, upland jack pine, emergent/wet meadow, mixed lowland conifer/hardwood and water (Table 11). Agricultural cropland, orchard and northern hardwood were avoided ($P < 0.10$). Preference and avoidance were indicated but not significant in 5 other classes, including urban, extractive, black spruce and other conifers (Table 11).

## DISCUSSION

One of the clearest patterns from this analysis is that BA land cover composition is representative of land cover composition of the NLP and changes over time are similar for both areas. This is possibly due to sampling effect since the larger buffer distance (5 km radius) used for BAs translates into a circular area of 78 $km^2$. Over all BAs, this is a large area and accounts for a greater proportion of the study area than using individual nest areas (generally 500 meters). While this needs to be taken into consideration, some results are notable.

While temporal changes of land cover in BAs tended to occur in the same direction as in the NLP, there were two exceptions. Herbaceous openland decreased slightly in the NLP, probably due to succession. There was no preference for this class, but it increased by nearly 50% in BAs from 1978 to 1993, and was present in nearly the same proportion as in the NLP in 1993 (Table 8). This disagrees with the general preference for forested areas but is probably a result of the increasing number of BAs

Table 11. Habitat selection of nesting bald eagles in the northern lower peninsula of Michigan, determined by confidence intervals of proportion of land cover composition within 5-kilometer breeding areas representing used resource.

| GAP class description | Lower CL | Upper CL | Proportion Available | Resource Selection | P |
|---|---|---|---|---|---|
| High intensity urban | 0.022 | 0.032 | 0.035 | Avoid | N.S.* |
| Low intensity urban | 0.002 | 0.006 | 0.005 | | |
| Extractive | 0.003 | 0.007 | 0.002 | Prefer | N.S. |
| Agricultural crops | 0.075 | 0.093 | 0.181 | Avoid | 0.0001 |
| Orchard / vineyard | 0.000 | 0.002 | 0.007 | Avoid | 0.0500 |
| Herbaceous openland | 0.053 | 0.067 | 0.065 | | |
| Shrubland | 0.013 | 0.021 | 0.016 | | |
| Other broad-leaved deciduous forest | 0.001 | 0.004 | 0.004 | | |
| Northern hardwood | 0.107 | 0.126 | 0.174 | Avoid | 0.0001 |
| Northern hardwood / conifer | 0.027 | 0.038 | 0.020 | Prefer | 0.0001 |
| Aspen / birch | 0.133 | 0.155 | 0.119 | Prefer | 0.0500 |
| Oak | 0.053 | 0.068 | 0.039 | Prefer | 0.0001 |
| Oak / jack pine | 0.001 | 0.005 | 0.002 | | |
| Other coniferous forest | 0.013 | 0.021 | 0.013 | Prefer | N.S. |
| White pine | 0.000 | 0.001 | 0.001 | | |
| Red pine | 0.042 | 0.055 | 0.043 | | |
| Upland jack pine | 0.087 | 0.106 | 0.062 | Prefer | 0.0001 |
| Cedar Spruce Fir | 0.000 | 0.003 | 0.001 | | |
| Emergent wetland / wet meadow | 0.019 | 0.029 | 0.014 | Prefer | 0.0001 |
| Other lowland shrub | 0.003 | 0.008 | 0.005 | | |
| Lowland broad-leaved deciduous shrub | 0.020 | 0.029 | 0.025 | | |
| Lowland broad-leaved evergreen shrub | 0.000 | 0.003 | 0.001 | | |
| Other forested wetland | 0.001 | 0.003 | 0.002 | | |
| Mixed lowland hardwood | 0.013 | 0.022 | 0.018 | | |
| Lowland jack pine | 0.000 | 0.002 | 0.001 | | |
| Black spruce | 0.002 | 0.006 | 0.002 | Prefer | N.S. |
| Northern white cedar | 0.000 | 0.003 | 0.001 | | |
| Mixed lowland conifer/hardwood | 0.113 | 0.134 | 0.080 | Prefer | 0.0001 |
| Barren land | 0.000 | 0.003 | 0.004 | Avoid | N.S. |
| Water | 0.063 | 0.079 | 0.055 | Prefer | 0.0500 |
| Urban grassland | 0.001 | 0.003 | 0.005 | Avoid | N.S. |
| Lowland needle-leaved evergreen shrub | 0.000 | 0.001 | 0.000 | | |

* N.S. - Selection indicated but not significant

covering more of the total NLP area. The fluctuations of this class are probably due to sampling effect rather than changing preferences. However, it could also be indicative of pairs settling farther from optimal habitat as the breeding population approached saturation. Lowland shrub also showed a reverse temporal trend in BAs, but only changed minimally in both BAs and the NLP (Table 7). There were also difficulties in assigning this GAP class to the 1978 MIRIS classes and most likely explains the inconsistency.

Significant temporal changes in land cover composition of BAs seems to show a slight trend away from general nesting habitat preferences of forested areas near water (Buehler 2000) with little disturbance (Grubb et al. 1992, Grubb and Bowerman 1997). This typically involved a decrease in lowland classes accompanied by an increase in upland and urban classes (Table 9), but is probably not indicative of changing preferences for several reasons. Intolerance of disturbance is usually exhibited within 500 meters of active nest sites (Fraser et. al. 1985, Grubb et al. 1992, Livingston et. al. 1990) but the BAs encompass a much larger area including land cover within 5 km. Increase in urban / industrial and cropland within BAs is probably due more to the overall increase in these classes in the NLP. This will not necessarily have an affect if active nests are still more than 500 meters from these areas.

Some classes (e.g., barren land, white cedar, oak / jack pine) that increased in BAs from 1978 to 1993 occurred at fairly low levels in both time periods and probably have no real affect even though statistically significant (Table 9). The mixed hardwood / conifer classes were GAP classes that had no equivalent MIRIS classes so it is impossible to determine the true extent of the change in these areas. Of those classes that decreased in BAs, most were only present at a low percent area in both time periods and probably do not represent any true correlation. These tended to be lowland classes and may be another indication of the increased number of breeding pairs in 1993, forcing a greater proportion of pairs to nest farther from bodies of water.

Both oak and white pine showed a more extreme decrease in area within BAs than in the NLP, but may again be a result of misclassification in converting MIRIS classes to GAP classes. The MIRIS classification scheme distinguished between upland and lowland areas predominated by these two species while the GAP classification scheme did not. This led to some lowland MIRIS classes being converted to lowland GAP classes without a predominant species. However, this could be indicative of succession and land management causing relatively pure stands in 1978 to become more mixed by 1993. Either way, it is difficult to determine if there is a real relationship to bald eagle BAs in this trend.

Of the 8 classes that occurred in greater percentages in active BAs than in inactive BAs, only mixed lowland conifer / hardwood and upland jack pine averaged more than 2.0%. However, mixed lowland conifer / hardwood was one of the classes without any equivalent MIRIS class. The time periods were grouped for this analysis, and there were more active BAs from the 1993 time which would have included this class. This result is again inconclusive as there is no way to determine to what extent this type of mixed class occurred in the 1978 BAs. Of the 3 classes occurring in greater percentages in inactive BAs, all averaged less than 5.0% in both activity categories (Table 10). Mixed lowland hardwood was present to the greatest extent in inactive BAs but this could again be due to problems in cover class scheme conversion rather than a true difference. The 1978 cover classes were specific to predominant species so that classes such as lowland oak would have been converted to the oak GAP class rather than being grouped with other lowland hardwoods.

The same problems occurred in analyzing differences between production categories, but are at least a bit more consistent with what would be expected. Of the 3 classes greater in productive than failed BAs, only red pine was present in any appreciable amount (Table 10). However, it is unclear if this is due to the discrepancies in classification schemes when there were more productive BAs from the 1993 time period. Even if there is a real difference in this class, it is again more likely due to the increased number of BAs being established farther from water and including more upland area. Only two classes (shrubland and cedar/spruce/fir) were present in greater amounts in failed BAs. However, both averaged less than 3.0% of BA composition and probably had no affect on productive outcome.

Because of the inconsistencies incurred by using two classification schemes, it is difficult to determine which results are truly indicative of temporal changes or differences in activity and production categories. Resource selection analysis results were more consistent though. Since only 1993 BAs and land cover were used, the results can also be considered more dependable. Preferred land cover classes are primarily those that would be associated with lowland areas in close proximity to water and relatively undisturbed areas (Table 11). Even for the larger scale BAs, this is still consistent with preferences in nest site selection (Buehler 1995, Swenson et al. 1986, Mathisen 1968, Grubb et al. 1992).

The preference for mixed classes agrees with the quality of high foliage height diversity and relatively open canopies that tend to characterize nesting areas (Buehler 2000). Even the preference for oak and upland jack pine are not inconsistent, as these classes can indicate the increased upland area covered by a greater number of BAs. These classes may also be included in areas that are forested and relatively undisturbed. These reasons may have led to the classification of these two as preferred even without the closer proximity to water. Most avoided classes (both significant and non-significant) are also consistent with nesting habitat characteristics, as most are non-forested or associated with greater human activity (agriculture, urban, barren land, urban grassland; Table 11). Avoidance of northern hardwoods was not expected, but may be due to the relative nature of compositional data (Aebischer et al. 1993). Preference in other forested classes will necessarily lead to a supposed avoidance of others. Overall, resource selection results are consistent with both general nesting area preferences and the results of the smaller scale analysis conducted on nest sites in the Black River Watershed.

## LIMITATIONS AND MANAGEMENT IMPLICATIONS

Results of this analysis do indicate some obvious patterns, but these should be considered cautiously due to limitations of the analysis. While the use of two time periods for land cover allowed examination of temporal changes, the attempt to equalize two land classification systems caused many difficulties in interpreting results. Because of this, it is impossible to determine if true differences occurred, or if they were simply different because of the way cover classes were converted. This means that analyses involving both time periods should be considered inconclusive even when consistent with what would be expected of bald eagle breeding habitat.

Resource selection analysis should also be considered carefully. A problem typically encountered with compositional data is that proportional composition is not independent. An increase in one cover class will lead to a decrease in another cover class. For this reason, a preference in one class will inevitably lead to an apparent avoidance of another class (Aebischer et al. 1993), so there were some concerns in using the Neu method (Neu et al. 1974). This constraint was ultimately considered acceptable though following a comparison of selection analysis methods conducted by McClean et al. (1998). The authors found that the Neu method was the only method that identified selection patterns consistent with known requirements and did so across several spatial scales. The relatively large sample size (n=107) also adds to the power of this analysis, in that a statistical preference or avoidance is likely to be indicative of true selection over this number of BAs.

In spite of these limitations, there are trends that may be useful. Land cover among BAs is less variable than among nests (BRW), but the overall habitat preferences typically agree. For the most part, analysis of BA composition seemed to result in a generalized version of the results indicated in individual nest composition (BRW). This is probably a combination of the more general GAP classification scheme and the larger area encompassed by BAs. The greater amount of area will cause BA composition to approach the composition available across the entire NLP, so results will not be as focused as with individual nest areas. This does not imply that this analysis cannot be useful though. While specific nesting habitat should be managed for its affect on nest placement, the larger BA habitat should not be overlooked. This broader area may play a role in providing additional foraging opportunities, amount of cover, proximity of potential disturbance, predator abundance and other factors that may affect successful reproduction.

The use of BAs rather than individual nest sites adds the component of considering all nests associated with a bald eagle breeding pair. This allows consideration of bald eagle breeding habitat variables beyond an actively defended nest. The method used for delineating BAs is by no means the best possible, but it can be viewed as a starting point. Relatively simple modifications can be made that may more accurately reflect the dynamics that occur within BAs. For example, the buffer radius could be changed and based more specifically on home range data or the average distance between breeding pairs. More linear buffers could be could be constructed for Great Lakes and riverine BAs. This would allow for more accurate compositions of these areas where eagle movements also tend to be more linear (Harmata and Montopoli 2001).

Weighting nests based on existence and activity is a fairly simple idea. However, it shifts placement of BA boundaries based on the most consistently active area while still accounting for all nests within the BA. It also adds the possibility of including BAs that have been inactive for several years. This may be a better measure of habitat affects on activity since activity / inactivity is independent at the level of BA but not for individual nests within BAs. While the results of these analyses may be largely inconclusive, this study offers a method of adding a spatial component to BAs rather than just using active nests that tend to change over time.

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# CHAPTER 4

# LAND USE / LAND COVER PATTERNS AND HABITAT MODEL FOR BALD EAGLE NESTS IN THE NORTHERN LOWER PENINSULA OF MICHIGAN

## INTRODUCTION

In pre-settlement Michigan, the bald eagle historically nested throughout the state where suitable habitat occurred. Through the early and mid-1900's, the population gradually declined due to loss of habitat and prey resources, direct control by humans and low productivity due to environmental contaminants (Barrows 1912, Brewer and McPeek 1991). To address this, an annual statewide monitoring program was initiated in 1961, providing over 40 years of information on nest location and production.

The Michigan bald eagle breeding population has rapidly expanded (after removal of the primary stressor, organochloride contaminants) but this has occurred in a landscape much different from what had previously been available. As the landscape continues to change, identification of unused but suitable nest habitat becomes more important. Habitat models can be a useful tool in determining potential of existing habitat. Bowerman (1993) developed a nesting habitat model for the Great Lakes region using Pattern Recognition to model the search image used in aerial habitat surveys. The model successfully classified 82% of known breeding areas as being located in good habitat, but the model was developed to identify potential nesting habitat only along the Great Lakes shoreline. Since this model only included area within 1.6 km of the Great Lakes shoreline, it may not apply as accurately to inland areas. Another difficulty in applying this method is that it is based on aerial surveys and the cost of flight time can be prohibitive.

One method that may be more efficient is to model bald eagle nesting habitat using digital land use / cover data obtained from remote sensing techniques. The current Michigan bald eagle data set, coupled with the increasing availability of digital spatial data, provides an excellent resource in determining spatial patterns of land use / cover associated with bald eagle nest location and productivity. Specific objectives of this analysis were to apply a GIS to determine landscape scale patterns of land cover associated with bald eagle nests, and to determine differences in land cover between productive and failed nests. A nesting habitat model was developed to determine if land cover data derived from satellite imagery could sufficiently identify potential bald eagle breeding habitat in Michigan on a regional scale.

## STUDY AREA

Because standard, annual data collection on bald eagles did not begin until after the species had become restricted to northern Michigan, the majority of breeding locations are distributed throughout the NLP and UP. To conduct analysis on this broad a spatial scale, regional land cover data was needed. The availability of existing GIS coverages of this geographic extent focused the study on the NLP (Figure 4, Chapter 3). The most common land cover types in this region are cropland, northern hardwood forests and aspen / white birch forests, which together comprise approximately 45% of the region's land cover.

## METHODS

### *Data Preparation*

A GIS coverage of regional land use / land cover data for 1993 in the GAP land classification scheme was obtained from the MDNR Wildlife Division. The ArcView extension XTools (DeLaune 2001) was used to select nests falling within the study area by using the clip command to clip the NLP area from a statewide nest location coverage (Appendix I). Sample selection was further refined by using only those nests in the NLP that existed at some time within a 3-year period centered on the land cover data year (n = 211), providing a sample of NLP nests existing from 1992 to 1994. Production records for these nests were used to determine whether each nest was productive (P) or failed (F) for each year it existed. Because activity and production are variable across years for individual nests, only those nests that existed in the same year as the land cover data (1993) were used for production analysis.

To use logistic regression for modeling nest areas compared to unused sites, random points were needed to represent unused sites. The ArcView extension Random Points Generator (Jenness 2001) was used to generate a set of 211 random points (equal to the number of nests). Since bald eagles are known to be closely associated with major water bodies, distance to water was also calculated for inclusion in the logistic regression model.

A hydrology coverage was developed using a hydrology polygon coverage created from 1983 U.S. Geological Survey (USGS) 1:100,000 digital line graphs (DLG). Great Lakes shoreline was added by creating an ArcView polygon shapefile of a box larger than the geographic extent of the entire state. This was converted to an Arc / Info coverage. Using the 1978 statewide MIRIS land cover coverage to delineate the state boundary, the Arc / Info erase command was executed to erase the extent of the state coverage from the box. The resulting coverage provided a polygon of the Great Lakes shoreline. This was merged with the 1983 USGS hydrology coverage to provide a complete hydrology coverage. An AML script was used in Arc / Info to calculate the distance from each nest and random point to the nearest body of water using the point locations and hydrology coverage.

Since some classes are highly variable across nests and there were over 30 land classes, the decision was made to reduce the number of variables to 20 cover classes. This would reduce the affect of species-predominant classes which are biased toward pine in the GAP scheme and provide more consistent variables across nests. Similar land cover classes were grouped to reduce the number of land cover variables to 19. For instance, all forested and shrub wetland classes were combined into a single forested/shrub wetland class. Distance to water was used as the last variable.

### *GIS and Statistical Analysis*

Land cover was summarized by 32 GAP land cover classes for the entire study area, and percent of total area was calculated for each class. Nest sites and associated land use / cover were evaluated by buffering each nest with a circular buffer of 500-meter radius. This distance was chosen because most disturbance responses of nesting eagles to humans or conspecifics are induced within 500 meters (Fraser et. al. 1985, Grubb et al. 1992, Livingston et. al. 1990). This distance is also comparable to a tertiary disturbance buffer zone described in the management guidelines of the Northern States Bald Eagle

Recovery Plan (Grier et al. 1983). The ArcView extension XTools (DeLaune 2001) was used to intersect nest site buffer zones with GAP land cover data to determine land cover within 500 meters surrounding each nest (Figure 3, Chapter 3). The resulting nest site land cover was summarized by GAP land cover class and percent area of each class was calculated for each nest area. Percent land cover associated with random points was determined using the same method as that used for nests.

To determine if nest site land cover had any significant affect on production, a Mann-Whitney U ($\alpha = 0.10$) was used to test all land cover classes for differences between production categories. Preference or avoidance in nest site land cover was analyzed using Resource Selection Analysis Software (Leban 1999). All 32 GAP cover classes and 111 randomly selected nests (those used to test the logistic regression model) were analyzed. Land cover composition of the entire NLP was designated as available resource. The data matrix was prepared by pairing each nest area composition (used resource) with NLP composition (available resource). The matrix was entered into the software and analyzed using the Neu et al. (1974) method ($\alpha = 0.10$), which combines the use of chi-square goodness-of-fit analysis and construction of Bonferroni simultaneous confidence intervals. The result is preference, avoidance, or neither based on where the predicted use value falls in reference to the confidence interval. For instance, if the lower confidence limit of used resource is greater than the predicted value, that class is considered preferred.

Logistic regression was evaluated using a cross-validation procedure to determine the predictive value of this approach. Twenty models were generated and tested using random selections of both nests and random points. To accomplish this, approximately half (100 of 211) of existing nests were randomly selected using the ArcView extension Animal Movement (Hooge 2001). These were designated as "model" nests that would be used for estimating land cover parameters through logistic regression. The remaining nests were designated "test" nests that would be used to validate the model. The random selection process was repeated with the random point set to provide a model and test set of unused resources. All model points (nests) were designated as used (1) and the model random points were designated as unused (0). The remaining 111 nests (1) and 111 random points (0) were used as test points to validate the corresponding model. The entire process was iterated 20 times to develop 20 model data sets of used and used points, each with a corresponding test data set.

Matrices were developed for each of the model data sets using distance to water and land cover composition of each point represented by percent area of the 19 grouped land cover classes. Each dataset was entered into NCSS 2000 (NCSS Statistical Software, Kaysville, Utah) and run through the logistic regression analysis. The data were analyzed using backward variable selection with a 0.20 selection cutoff and 0.50 classification midpoint and a maximum of 20 iterations. The average percent correct classification by group (0 or 1), percent correct total classification, percent omission error (number of nests incorrectly classified as unused out of the total number of nests) and percent total omission error (number of nests incorrectly classified as unused out of the total number of point classified as unused) was calculated across all 20 of the resulting models.

Land cover composition and distance to water of each test dataset was run through the model developed by its corresponding model points. The average was calculated for these test sets for percent correct classification by group (0 or 1), percent correct total classification, percent omission error and percent total omission error. The averages, percent classification rates and number of times each variable occurred in the model were examined across all iterations for both model and test data to provide a measure of the predictive accuracy of this method.

## RESULTS

Two-hundred eleven nests existed in the NLP between 1992 and 1994. Occurrence of land cover classes was highly variable, ranging from those occurring in only 1% of nests to those occurring in 80% of nests (Table 12). No classes occurred within 500 m of all nests. Four classes (Aspen/Birch, emergent wetland, water and mixed lowland conifer/hardwood) were present in at least two-thirds of the nest areas (Table 12). Eighty-seven nests were active in 1993, 55 productive and 32 failed. Differences between productive and failed nests occurred in 5 land cover classes ($P < 0.10$, Table 13). Only 2 of these classes, northern hardwood and lowland broad-leaved deciduous shrub, averaged >5% of nest areas in either production group. The percent of water within 500 m of nests, while not significantly related to production, was more than 50% greater at productive nests than failed nests.

Resource selection analysis resulted in 8 preferred cover classes ($P < 0.10$), primarily those associated with lowland areas (e.g., emergent wetland, northern white cedar, mixed lowland conifer/hardwood, Table 14). Seven classes, mostly urban, openland and agriculture, were avoided (Table 14). Preference was indicated but not significantly in red pine, forested wetland and lowland evergreen shrub. Avoidance was

Table 12. Number and percent of bald eagle nests with land cover classes occurring within 500 meters of nests in the northern lower peninsula of Michigan.

| GAP class description | # of nests | % of nests |
|---|---|---|
| High intensity urban | 53 | 25 |
| Low intensity urban | 3 | 1 |
| Extractive | 7 | 3 |
| Agricultural crops | 105 | 50 |
| Orchard / vineyard | 2 | 1 |
| Herbaceous openland | 128 | 61 |
| Shrubland | 94 | 45 |
| Other broad-leaved deciduous forest | 33 | 16 |
| Northern hardwood | 128 | 61 |
| Northern hardwood / conifer | 80 | 38 |
| Aspen / birch | 168 | 80 |
| Oak | 100 | 47 |
| Oak / jack pine | 9 | 4 |
| Other coniferous forest | 64 | 30 |
| White pine | 6 | 3 |
| Red pine | 122 | 58 |
| Upland jack pine | 136 | 64 |
| Cedar Spruce Fir | 15 | 7 |
| Emergent wetland / wet meadow | 139 | 66 |
| Other lowland shrub | 34 | 16 |
| Lowland broad-leaved deciduous shrub | 79 | 37 |
| Lowland broad-leaved evergreen shrub | 23 | 11 |
| Other forested wetland | 24 | 11 |
| Mixed lowland hardwood | 65 | 31 |
| Lowland jack pine | 5 | 2 |
| Black spruce | 52 | 25 |
| Northern white cedar | 19 | 9 |
| Mixed lowland conifer / hardwood | 168 | 80 |
| Barren land | 6 | 3 |
| Water | 141 | 67 |
| Urban grassland | 6 | 3 |
| Lowland needle-leaved evergreen shrub | 10 | 5 |

Table 13. Mean of percent land cover by cover class within 500 meters of bald eagle nests in the northern lower peninsula of Michigan for each production group.

| GAP class description | P * | F | P |
|---|---|---|---|
| High intensity urban | 0.98 | 0.51 | 0.17 |
| Low intensity urban | 0.03 | 0.05 | 0.30 |
| Extractive | 0.32 | 0.85 | 0.28 |
| Agricultural crops | 2.12 | 4.51 | 0.09 |
| Orchard / vineyard | 0.00 | 0.02 | 0.20 |
| Herbaceous openland | 4.90 | 5.21 | 0.85 |
| Shrubland | 0.55 | 2.27 | 0.01 |
| Other broad-leaved deciduous forest | 0.12 | 0.40 | 0.16 |
| Northern hardwood | 7.40 | 10.32 | 0.03 |
| Northern hardwood / conifer | 3.41 | 2.63 | 0.41 |
| Aspen / birch | 13.00 | 11.94 | 0.73 |
| Oak | 4.33 | 8.31 | 0.67 |
| Oak / jack pine | 0.10 | 0.07 | 0.30 |
| Other coniferous forest | 1.23 | 0.40 | 0.23 |
| White pine | 0.01 | 0.01 | 0.91 |
| Red pine | 5.49 | 2.60 | 0.18 |
| Upland jack pine | 7.85 | 5.16 | 0.85 |
| Cedar Spruce Fir | 0.09 | 0.30 | 0.44 |
| Emergent wetland / wet meadow | 7.06 | 6.88 | 0.40 |
| Other lowland shrub | 0.94 | 1.70 | 0.83 |
| Lowland broad-leaved deciduous shrub | 3.28 | 5.82 | 0.07 |
| Lowland broad-leaved evergreen shrub | 0.55 | 0.05 | 0.16 |
| Other forested wetland | 0.52 | 0.30 | 0.96 |
| Mixed lowland hardwood | 2.37 | 1.64 | 0.75 |
| Lowland jack pine | 0.24 | 0.07 | 0.62 |
| Black spruce | 1.08 | 0.15 | 0.27 |
| Northern white cedar | 0.58 | 0.02 | 0.14 |
| Mixed lowland conifer / hardwood | 17.84 | 18.17 | 0.96 |
| Barren land | 0.00 | 0.63 | 0.02 |
| Water | 13.32 | 8.68 | 0.13 |
| Urban grassland | 0.23 | 0.05 | 0.30 |
| Lowland needle-leaved evergreen shrub | 0.03 | 0.27 | 0.90 |

* Production groups: P – productive, F – Failed

Table 14. Habitat selection of nesting bald eagles in the northern lower peninsula of Michigan, determined by confidence intervals of proportion of land cover composition within 500 meters of nests representing used resource.

| GAP class description | Lower CL | Upper CL | Proportion Available | Resource Selection | P |
|---|---|---|---|---|---|
| High intensity urban | 0.004 | 0.009 | 0.035 | Avoid | 0.0001 |
| Low intensity urban | 0.000 | 0.001 | 0.005 | Avoid | 0.0500 |
| Extractive | 0.002 | 0.006 | 0.002 | | |
| Agricultural crops | 0.020 | 0.029 | 0.181 | Avoid | 0.0001 |
| Orchard/vineyard | 0.000 | 0.000 | 0.007 | Avoid | 0.0001 |
| Herbaceous openland | 0.034 | 0.046 | 0.065 | Avoid | 0.0001 |
| Shrubland | 0.005 | 0.010 | 0.016 | Avoid | 0.0500 |
| Other broad-leaved deciduous forest | 0.000 | 0.002 | 0.004 | Avoid | N.S.* |
| Northern hardwood | 0.073 | 0.089 | 0.174 | Avoid | 0.0001 |
| Northern hardwood/conifer | 0.026 | 0.036 | 0.020 | Prefer | 0.0001 |
| Aspen/Birch | 0.102 | 0.121 | 0.119 | | |
| Oak | 0.050 | 0.064 | 0.039 | Prefer | 0.0001 |
| Oak/jack pine | 0.000 | 0.001 | 0.002 | Avoid | N.S. |
| Other coniferous forest | 0.007 | 0.013 | 0.013 | | |
| White pine | 0.000 | 0.000 | 0.001 | Avoid | N.S. |
| Red pine | 0.046 | 0.060 | 0.043 | Prefer | N.S. |
| Upland jack pine | 0.060 | 0.075 | 0.062 | | |
| Cedar Spruce Fir | 0.000 | 0.003 | 0.001 | | |
| Emergent wetland/wet meadow | 0.051 | 0.065 | 0.014 | Prefer | 0.0001 |
| Other lowland shrub | 0.003 | 0.007 | 0.005 | | |
| Lowland broad-leaved deciduous shrub | 0.031 | 0.042 | 0.025 | Prefer | 0.0500 |
| Lowland broad-leaved evergreen shrub | 0.001 | 0.004 | 0.001 | Prefer | N.S. |
| Other forested wetland | 0.002 | 0.006 | 0.002 | Prefer | N.S. |
| Mixed lowland hardwood | 0.013 | 0.021 | 0.018 | | |
| Lowland jack pine | 0.000 | 0.002 | 0.001 | | |
| Black spruce | 0.007 | 0.013 | 0.002 | Prefer | 0.0001 |
| Northern white cedar | 0.006 | 0.011 | 0.001 | Prefer | 0.0001 |
| Mixed lowland conifer/hardwood | 0.213 | 0.239 | 0.080 | Prefer | 0.0001 |
| Barren land | 0.001 | 0.003 | 0.004 | Avoid | N.S. |
| Water | 0.121 | 0.141 | 0.055 | Prefer | 0.0001 |
| Urban grassland | 0.001 | 0.004 | 0.005 | Avoid | N.S. |
| Lowland needle-leaved evergreen shrub | 0.000 | 0.001 | 0.000 | | |

* N.S – selection indicated but not significant

indicated for white pine, oak/jack pine, urban grassland and barren land. All other classes were neither preferred nor avoided (Table 14).

Occurrence of the 19 grouped land cover classes (Table 15) used in developing the logistic regression model was highly variable among nests. The presence of these classes ranged from lowland jack pine present in only 2% of nests to aspen/birch and mixed lowland conifer/hardwood occurring in 80% of nests (Table 16). No classes occurred within 500 m of all nests. Five classes (aspen/birch, emergent wetland, water, mixed lowland conifer/hardwood and barren/open/shrubland) were present in at least two-thirds of the nest areas (Table 16).

Distance to water was the only variable present in all models and always had a negative coefficient, indicating that as the distance decreases the suitability of the location increase (Table 17). All other variables had positive coefficients for most of the models in which they occurred, so that the increased percent of these classes should indicate greater suitability. However, model iterations 4 – 6 exhibited negative coefficients for all variables included. The number of variables occurring in each of the 20 model iterations ranged from 6 (occurring in 4 model iterations) to 20 (occurring in 6 iterations) (Table 17). Four of the land cover variables (oak/jack pine/upland jack pine, mixed lowland conifer/hardwood, forested/shrub wetland and emergent wetland) occurred in >75% and lowland jack pine occurred in 50% of the 20 iterations (Table 17). Two cover classes, aspen/birch and oak, occurred in 14 of the 20 iterations, but tended to be included in the more complex models consisting of 10 or more variables (Table 17). While distance to water occurred in all 20 iterations, water as a cover class occurred in only 13 models.

Table 15. Land cover class groupings used for bald eagle nesting habitat model of the northern lower peninsula of Michigan.

| Classes used in logistic regression model | GAP classes included in model class |
|---|---|
| Oak/jack pine/Upland jack pine | oak/jack pine, upland jack pine |
| Mixed lowland conifer/hardwood | mixed lowland conifer/hardwood |
| Forested/Shrub wetland | other lowland shrub, lowland broad-leaved deciduous shrub, lowland broad-leaved evergreen shrub, other forested wetland, lowland needle-leaved evergreen shrub |
| Emergent wetland/wet meadow | emergent wetland/wet meadow |
| Aspen/Birch | aspen/birch |
| Oak | oak |
| Water | water |
| Red pine | red pine |
| Northern hardwood/other broad-leaved decid. | other broad-leaved deciduous forest, northern hardwood |
| Mixed lowland hardwood | mixed lowland hardwood |
| Lowland jack pine | lowland jack pine |
| Urban/Extractive | high intensity urban, low intensity urban, extractive, urban grassland |
| Agricultural/Orchard | agricultural crops, orchard/vineyard |
| Barren/Open/Shrubland | barren land, herbaceous openland, shrubland |
| Northern hardwood/conifer | northern hardwood/ conifer |
| White Pine/Other coniferous | white pine, other coniferous forest |
| Cedar Spruce Fir | cedar spruce fir |
| Black spruce | black spruce |
| Northern white cedar | northern white cedar |

Table 16. Number and percent of bald eagle nests with model land cover classes occurring within 500 meters of nests in the northern lower peninsula of Michigan.

| GAP class description | # of nests | % of nests |
|---|---|---|
| Urban / Extractive | 61 | 29 |
| Agricultural / Orchard | 105 | 50 |
| Barren / Open / Shrubland | 145 | 69 |
| Northern hardwood / Other broad-leaved deciduous | 129 | 61 |
| Northern hardwood / conifer | 80 | 38 |
| Aspen / birch | 168 | 80 |
| Oak | 100 | 47 |
| Oak / jack pine / Upland jack pine | 136 | 64 |
| White pine / Other coniferous | 67 | 32 |
| Red pine | 122 | 58 |
| Cedar Spruce Fir | 15 | 7 |
| Emergent wetland / wet meadow | 139 | 66 |
| Forested / Shrub wetland | 124 | 59 |
| Mixed lowland hardwood | 65 | 31 |
| Lowland jack pine | 5 | 2 |
| Black spruce | 52 | 25 |
| Northern white cedar | 19 | 9 |
| Mixed lowland conifer / hardwood | 168 | 80 |
| Water | 141 | 67 |

Table 17. Summary of logistic regression model variables with coefficient signs for bald eagle nesting habitat potential in the northern lower peninsula of Michigan.

| Land Cover Class | Iteration 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | No. of times class occurred in model |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Distance to water (m) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 20 |
| Oak / jack pine / upland jack pine | + | + | + | | - | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | 19 |
| Mixed lowland conifer / hardwood | + | + | + | | - | | + | + | + | + | + | + | + | + | + | + | + | + | + | + | 18 |
| Forested / shrub wetland | + | + | + | | - | | + | + | + | + | + | + | + | | + | + | + | + | + | + | 17 |
| Emergent wetland / wet meadow | + | + | + | | - | | + | + | | + | + | + | + | + | + | + | + | + | | + | 16 |
| Aspen / birch | | + | + | | - | - | | + | | + | | + | + | | + | + | + | + | + | + | 14 |
| Oak | | + | + | | - | | + | + | + | | + | + | + | + | | + | + | + | + | | 14 |
| Water | | + | | - | - | - | + | + | | | | + | + | + | + | + | + | + | | | 13 |
| Red pine | | + | | - | - | - | | + | | | | + | + | | + | + | | + | | + | 11 |
| Northern hardwood / other decid. | | + | | - | - | - | | + | | | | + | + | | | + | + | + | | | 10 |
| Mixed lowland hardwood | | + | | | - | | + | + | | | | + | + | + | | + | | + | | + | 10 |
| Lowland jack pine | + | + | | | | | + | + | + | | | + | + | | | + | | + | | + | 10 |
| Urban / extractive | | + | | - | - | - | | + | | | | + | + | | | + | | + | | | 9 |
| Agriculture / orchard | | + | | - | - | - | | + | | | | + | + | | | + | | + | | | 9 |
| Barren / open / shrubland | | + | | | - | | + | + | | | | + | + | | + | + | | + | | | 9 |
| Northern hardwood / conifer | | + | | | - | - | | + | | | | + | + | + | | + | | + | | | 9 |
| White pine / other coniferous | | + | | - | - | | | + | | | | + | + | | | + | | + | | | 8 |
| Cedar Spruce Fir | | + | | | | | | + | + | | | + | + | | + | + | | + | | | 8 |
| Black spruce | | + | | | - | | | + | | | | + | + | | | + | | + | | | 7 |
| Northern white cedar | | + | | | | | | + | | | | + | + | | | + | | + | | | 6 |
| Number of variables in model | 6 | 20 | 7 | 7 | 17 | 9 | 10 | 20 | 7 | 6 | 6 | 20 | 20 | 8 | 10 | 20 | 9 | 20 | 6 | 9 | |

Distance to water averaged 741 m over all existing nests (Table 17). Of the 4 classes present in > 75% of models, only mixed lowland conifer / hardwood had a relatively high mean percent area (Table 18). The other 3 classes had only 5 – 7 % mean percent areas (Table 18). Water as a class and aspen / birch also were also among the highest in mean percent area, but occurred in only 60 – 65 % of models (Table 17). Lowland jack pine had the lowest mean percent area over all nests but occurred in half the models (Table 17). Mixed lowland hardwood and northern hardwood / other deciduous also occurred in half the models (Table 17).

P-values for distance to water were < 0.01 in all models. Land cover variables tended to fluctuate around 0.10 across all models in which those variables occurred (Table 19). On average, the models correctly classified 79% of all locations (nests and random points) and 83% of nests used to construct the models. This left 17% of model nest locations incorrectly classified as unused locations, and of all locations classified as unused, 19% were actually nests (Table 20). When the models were applied to test locations (nests and random points not used in model development), the model correctly classified 75% of all locations and 79% of nests (Table 20). For the test locations, 21% of nests were incorrectly classified as unused and 22% of all locations classified as unused were actually nests (Table 20). Random points classification rates were slightly lower than nests with 75% of the model locations and 72% of the test locations correctly classified (Table 20).

## DISSCUSSION

Bald eagle nest area land cover was highly variable in the NLP when considering

Table 18. Mean and median percent land cover of grouped land cover classes and distance to water for bald eagle nests existing in the northern lower peninsula of Michigan, 1992-1994.

| | Nests | |
|---|---|---|
| GAP class description | mean | median |
| Urban / Extractive | 1.28 | 0.00 |
| Agricultural / Orchard | 3.06 | 0.00 |
| Barren / Open / Shrubland | 5.23 | 1.50 |
| Northern hardwood / Other broad-leaved deciduous | 9.14 | 0.95 |
| Northern hardwood / conifer | 2.92 | 0.00 |
| Aspen / Birch | 11.22 | 5.00 |
| Oak | 4.86 | 0.00 |
| Oak / jack pine / Upland jack pine | 6.13 | 1.56 |
| White pine / Other coniferous | 0.94 | 0.00 |
| Red pine | 4.54 | 0.58 |
| Cedar Spruce Fir | 0.10 | 0.00 |
| Emergent wetland / wet meadow | 6.80 | 1.61 |
| Forested/Shrub wetland | 5.40 | 0.46 |
| Mixed lowland hardwood | 2.04 | 0.00 |
| Lowland jack pine | 0.09 | 0.00 |
| Black spruce | 0.80 | 0.00 |
| Northern white cedar | 0.90 | 0.00 |
| Mixed lowland conifer / hardwood | 20.53 | 13.88 |
| Water | 14.01 | 5.15 |
| Distance to water | 741.22 | 327.10 |

Table 19. Summary of logistic regression model variable P-values for bald eagle nesting habitat potential in the northern lower peninsula of Michigan.

| | Iteration | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land Cover Class | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| Distance to water (m) | -- * | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Oak/jack pine/upland jack pine | 0.07 | 0.18 | 0.08 | | 0.12 | 0.12 | 0.02 | 0.08 | 0.04 | -- | 0.01 | 0.15 | 0.15 | 0.01 | 0.06 | 0.12 | 0.04 | 0.19 | 0.13 |
| Mixed low. conifer/ hardwood | 0.04 | 0.18 | -- | | 0.11 | | 0.00 | 0.08 | -- | -- | -- | 0.15 | 0.15 | -- | -- | 0.12 | -- | 0.19 | -- |
| Forested / shrub wetland | 0.05 | 0.18 | 0.02 | | 0.12 | | 0.07 | 0.08 | -- | 0.02 | 0.12 | 0.15 | 0.15 | | -- | 0.12 | 0.01 | 0.19 | 0.01 |
| Emerg. wetland/wet meadow | 0.03 | 0.18 | 0.10 | | 0.12 | | 0.02 | 0.08 | | 0.02 | 0.03 | 0.15 | 0.15 | 0.05 | 0.08 | 0.12 | -- | 0.19 | |
| Aspen/birch | | 0.18 | 0.17 | | 0.11 | 0.00 | | 0.08 | | 0.09 | | 0.15 | 0.15 | | 0.04 | 0.12 | 0.01 | 0.19 | 0.16 |
| Oak | | 0.18 | 0.08 | | 0.12 | | 0.10 | 0.08 | 0.02 | | 0.01 | 0.15 | 0.15 | 0.10 | | 0.12 | 0.01 | 0.19 | 0.09 |
| Water | | 0.18 | | 0.15 | 0.11 | 0.04 | 0.09 | 0.08 | | | | 0.15 | 0.15 | 0.13 | 0.05 | 0.12 | 0.07 | 0.19 | |
| Red pine | | 0.18 | | 0.14 | 0.11 | 0.07 | | 0.08 | | | | 0.15 | 0.15 | | 0.06 | 0.12 | | 0.19 | |
| North. hardwood/other decid. | | 0.18 | | 0.01 | 0.11 | 0.00 | | 0.08 | | | | 0.15 | 0.15 | | | 0.12 | 0.20 | 0.19 | |
| Mixed lowland hardwood | | 0.18 | | | 0.14 | | 0.11 | 0.08 | | | | 0.15 | 0.15 | 0.08 | | 0.12 | | 0.19 | |
| Lowland jack pine | 0.16 | 0.18 | | | | | 0.06 | 0.08 | 0.08 | | | 0.15 | 0.15 | | | 0.09 | | 0.19 | |
| Urban/extractive | | 0.18 | | 0.15 | 0.10 | 0.11 | | 0.08 | | | | 0.15 | 0.15 | | | 0.12 | | 0.19 | |
| Agriculture/orchard | | 0.18 | | 0.00 | 0.10 | 0.00 | | 0.08 | | | | 0.15 | 0.15 | | | 0.12 | | 0.19 | |
| Barren/open/shrubland | | 0.18 | | | 0.11 | | 0.06 | 0.08 | | | | 0.15 | 0.15 | | 0.16 | 0.12 | | 0.19 | |
| Northern hardwood/conifer | | 0.18 | | | 0.12 | 0.17 | | 0.08 | | | | 0.15 | 0.15 | 0.07 | | 0.12 | | 0.19 | |
| White pine/other coniferous | | 0.18 | | 0.11 | 0.08 | | | 0.08 | | | | 0.15 | 0.15 | | | 0.12 | | 0.19 | |
| Cedar Spruce Fir | | 0.18 | | | | | | 0.08 | 0.14 | | | 0.15 | 0.15 | | 0.08 | 0.12 | | 0.19 | |
| Black spruce | | 0.18 | | | 0.14 | | | 0.08 | | | | 0.15 | 0.15 | | | 0.12 | | 0.19 | |
| Northern white cedar | | 0.18 | | | | | | 0.08 | | | | 0.15 | 0.15 | | | 0.12 | | 0.19 | |

* (--) Indicates P-value < 0.01

Table 20. Mean percent classification and omission error for bald eagle nesting habitat models constructed for the northern lower peninsula of Michigan.

| | Model Construction Data Set | | | | Test Data Set | | | |
|---|---|---|---|---|---|---|---|---|
| | % correct by group | % correct total | % omission error | % total omission | % correct by group | % correct total | % omission error | % total omission |
| Used | 83 | 79 | 17 | 19 | 79 | 75 | 21 | 22 |
| Unused | 75 | | | | 72 | | | |

all 32 GAP cover classes (Table 12), but also when only 19 grouped classes were considered (Table 16). However, in both cases the same 4 classes were consistently present in the majority of nests. Given that nesting bald eagles are known to be closely associated with water (Buehler 1995, Swenson et al. 1986), it was expected that the water cover class would tend to be present within 500 m of nests. The other 3 classes are also consistent as emergent wetland, mixed lowland conifer/hardwood and aspen/birch are typical of areas surrounding bodies of water in the NLP.

Of the 5 cover classes present in different proportions between productive and failed nests, all occurred at higher levels in failed nests. Agricultural cropland, shrubland and barren land occurred at < 5% in both categories so it is difficult to determine if the presence of these classes had any real affect on production. However, they may represent those nests that were placed in less than optimal areas. Agriculture near these nests may make them more prone to disturbance and increase the potential for nest abandonment (Fraser et. al. 1985, Grubb et al. 1992). Shrubland and barren land also occurred in low percent area but again may be indicative of nests that are in less forested areas making them more susceptible to disturbance or harsh weather.

The percent of northern hardwoods was also higher in failed nests but probably has little affect on production. It seems that a mixed class of this nature would provide the high foliage height diversity characteristic of bald eagle nest sites (Buehler 2000). This is a very broad class that does not distinguish between upland and lowland areas though. It is more likely that this class represents more upland area farther from water, which would also be less suitable for nesting. While the difference in amount of water within 500 m was not significant, productive nest areas consisted of 50% more water than failed nests. This is also consistent with the tendency of eagles to nest < 2 km from a body of water (Buehler 2000), but also indicates that the actual distance can play a role.

Resource selection analysis also provided results consistent with general nest site preferences (Buehler 1995, Swenson et al. 1986, Mathisen 1968, Grubb et al. 1992) but characterizes habitat use more specifically for Michigan. Preferred land cover classes are primarily those that would be associated with lowland areas in close proximity to water and relatively undisturbed areas (Table 14). The preference for mixed classes lends the quality of high foliage height diversity and relatively open canopies that tend to characterize nesting areas (Buehler 2000). Even the preference for oak is not inconsistent, as this class may also be included in areas that are forested and relatively undisturbed. This may have led to the classification of oak as preferred even without the closer proximity to water.

All 7 classes that were avoided represented areas prone to disturbance (urban) or were non-forested (agriculture, shrubland) (Table 14). Where avoidance was indicated but not significant tended to include classes that are more typically upland areas. This could be a result of nests occurring in areas that are usable but of marginal quality. The population had still not reached saturation at this time (1993) so it cannot be said that these areas were truly avoided. This trend may be due to a greater number of nests being placed farther away from water as the population expanded, but does not necessarily mean those nests were less successful. Avoidance of northern hardwoods was not expected, but may be due to the relative nature of compositional data (Aebischer et al. 1993). Preference in other forested classes will necessarily lead to a supposed avoidance of others. Overall, resource selection results are consistent with both general nesting area preferences and the results of the analyses conducted on nest sites in the Black River Watershed and BAs in the NLP.

Variables consistently present in the habitat models were again consistent with habitat preferences. These included mixed and lowland classes that would be typical of areas near water (Table 17). Distance to water was the only variable present in all 20 iterations of the model and with P-values $< 0.01$, indicating that this is probably the strongest factor in nest site selection for bald eagles (Table 19). Average omission errors in the model (known nests classified as unused locations), were fairly low for a model encompassing this large a spatial extent. This can be considered acceptable when the model was developed using nests over a short period of time. Some of those nests may be in lesser quality habitat, but pairs using those nests may have moved to other locations in the following years. This could be another result of population expansion as well, since increasing numbers of pairs will be forced to settle in sub-optimal areas as the optimal areas become saturated.

Commission errors (unused locations classified as nests) tended to be 10% higher than omission errors. This was not considered a problem though because the population in 1992 – 1994 had not even reached the recovery goal of 300 pairs yet. Some of those random points misclassified could very well have been suitable nesting areas and there just were not any pairs using them at that time. However, it would seem that if these areas were suitable they would have been used before those areas where known nests were misclassified as unused. It is not clear if this is due to inaccuracy of the model or some other confounding factor. Experience can play a role in nest site selection as well as distance to other breeding pairs. Random points classified as nests may have been in suitable areas concerning land cover but the density of previously existing nest areas may have precluded new pairs from utilizing these areas. In general, the model provided relatively high correct classification rates for nests in both the model and test data sets. If goodness-of-fit statistics are applied to determine a best model, this process could then be an adequate method for developing a model for identifying remaining nesting habitat potential in Michigan.

## LIMITATIONS AND MANAGEMENT IMPLICATIONS

Results of this study indicate certain characteristics of bald eagle nesting habitat in the NLP. However, resource selection and production analyses should be considered carefully. A problem typically encountered with compositional data is that proportional composition is not independent. An increase in one cover class will lead to a decrease in another cover class. For this reason, a preference in one class will inevitably lead to an apparent avoidance of another class (Aebischer et al. 1993), so there were some concerns in using the Neu method (Neu et al. 1974). This constraint was ultimately considered acceptable though following a comparison of selection analysis methods conducted by McClean et al. (1998). The authors found that the Neu method was the only method that identified selection patterns consistent with known requirements and did so across several spatial scales.

Another problem in interpreting these results is that there is not necessarily a causal effect. As indicated in the model, distance to water appears to be the key factor in where bald eagles will nest. Preferred land cover classes most likely are not being selected but are simply characteristic of lowland areas near water in the NLP. Still, suitable nest trees in relatively undisturbed areas are needed for nesting. This may place more emphasis on those areas that are avoided or that tend to occur in greater proportion in failed nests. It may, therefore, be just as important to identify suitable areas based on a lack of these classes.

Michigan's breeding eagle population has increased very rapidly, clouding the line between intolerance or simply taking what is available. Timing and type of disturbance may play a greater role in nest success than just the presence of human activity. A nest is less likely to be abandoned later in the season, but pairs may be more likely to accept some disturbance if it is already there when they begin nesting (S. Postupalsky, personal communication). This does not necessarily mean they will use the same nest again in following years if a more suitable area is available. Managers should keep in mind that as the eagle population continues to expand, the availability of optimal breeding areas will decrease, and as breeding pairs begin to settle in sub-optimal areas, they may experience lower reproductive rates. If the population experiences another serious decline caused by increased mortality (e.g., disease factors, environmental contaminants) optimal habitat may play an important role in maintaining reproductive success.

Whether the population experiences another dramatic decrease or continues expanding until usable habitat is saturated, a method for identifying suitable nesting areas will be a useful tool in management. The cross-validation procedure used for this study can provide direction in nest habitat identification, but these specific models should not be applied at this time. These models were based on 1993 data and cannot be accurately attributed to present conditions. Instead, they should be seen as a test of a method that can be performed efficiently while still providing sufficiently accurate results. Using only land cover classification and distance to water correctly identified approximately 80% of existing nests. This is comparable to Bowerman's (1993) pattern recognition model that used aerial habitat survey.

Since it would be difficult to apply a model from this study to land cover in a different classification system, it is recommended that the process be repeated first based on the newer land cover data that has only recently been released for Michigan. Until updated data can be obtained, the information gained from these models can still be used as a supplement to resource selection results to point out those land cover classes that appear to have the most affect on nest site suitability. For now, the results provide confirmation that distance to water is the most important factor, and that nests average ~ 750 m from the nearest water body. Areas matching this description can then be further investigated for presence or absence of land cover classes that are preferred or avoided. Results from production analysis can also provide greater insight in identifying those areas that are not only usable but are the most suitable.

Overall, a logistic regression model based on land use / cover data can provide an accurate means of identifying bald eagle nesting habitat over a large geographic extent, while focusing on land cover particular to the region, but may not be applicable to current conditions. If current land cover data can be obtained, it will more accurately represent the land cover that exists at present. Coupled with a nesting population that is now nearing habitat saturation, a more recent modeling process should provide a better measure of what is currently happening and provide better results in identifying remaining suitable habitat.

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CHAPTER 5

# MANAGEMENT IMPLICATIONS OF USING LAND USE / LAND COVER DATA FOR DETERMINING NESTING HABITAT OF BALD EAGLES IN MICHIGAN

## SUMMARY

In general, land cover among bald eagle nests and BAs is highly variable. However, land cover associated with nest sites in the BRW and NLP, and BAs in the NLP, are consistent with general habitat preferences of forested areas near (< 2 km) large bodies of water (Buehler 2000). These preferences also do not appear to be changing over time. Those classes that tend to occur most consistently during all time periods analyzed (Table 3, Table 8) also tend to characterize areas that are relatively undisturbed, near water, and predominated by super-canopy tree species (wetlands, aspen / birch, lowland conifer, lowland hardwood) with high foliage height diversity. These classes are also among those consistently preferred at all spatial scales, and classes that were avoided (urban / industrial, agriculture, open / shrub land) were typical of areas that are non-forested or prone to disturbance (Table 6, Table 11, Table 14). Although the habitat model was somewhat variable depending on the selection of nests used, the most consistent variables (Table 20) also agreed with general nest site preferences.

Land cover classes showing temporal trends counter to these preferences (urban, agriculture, uplands – jack pine / oak, and aspen / birch) are also those that typically have been the most intensively managed or subject to conversion. This could indicate a reduction of nests located on inland lakes, possibly due to increasing development and recreation on lakeshores. However, this could simultaneously be due to the increase in

the bald eagle nesting population. While eagle nesting habitat over the entire state was not saturated by 1992, the number of nesting pairs had nearly tripled since 1978. By the last period of this analysis, nest areas near water in the BRW and the entire NLP may have all been occupied, forcing newer pairs to establish nests farther away from lake and river shorelines.

Because of this, the temporal changes for those land cover classes should be interpreted as being due to land management practices rather than changing habitat preference of bald eagle breeding pairs. This implies that breeding pairs are not necessarily becoming more tolerant of less suitable areas, and those using less preferred habitat may experience a reduction in successful reproduction.

Differences in land cover between productive and failed nests (or BAs) tend to agree with nest site preference. Failed nests had higher proportions of open land and productive nests had higher proportions of forested area. However, in both groups of nests, significantly different land cover classes occurred in very low proportion (Table 5, Table 10, Table 13). Because so many other variables can affect reproduction as well, it is difficult to say if those classes that were different were truly affecting production. While classes higher in failed nests do not occur in any appreciable amount, these differences may still be evidence of lower success from factors associated with more open areas (i.e., lack of cover, increased disturbance or predation).

## LIMITATIONS

Results of this analysis indicate some obvious patterns, but these should be considered cautiously due to limitations of the analysis. While the BRW land cover time series allowed examination of temporal changes, the geographic extent is limiting. The combination of a small area (relative to bald eagle habitat use) and the reduced eagle population led to very small sample sizes. This in turn reduces the power of statistical analysis. This is somewhat alleviated by the quality of the land cover data. The land cover database was developed specifically to study changes over time in this region of the state (Rutledge 2001). Therefore, the land cover associated with eagle nests in the BRW can be considered reliable even if it the lack of nest sites does lend itself to hypothesis testing.

The affect of small sample size was overcome in considering the entire NLP when analyzing BAs, and the use of two time periods allowed examination of temporal changes as well. However, the attempt to equalize two land classification systems in this case caused many difficulties in interpreting results. Because of this, it is impossible to really determine if true differences occurred, or if they were simply different because of the way cover classes were converted. But most of the temporal changes in NLP BAs agreed with those in the BRW, adding some confidence to the results at both scales.

There was also a limitation in resource selection analysis, since proportional compositional data was used. A problem typically encountered with compositional data is that proportional composition is not independent. An increase in one cover class will lead to a decrease in another cover class. For this reason, a preference in one class will inevitably lead to an apparent avoidance of another class (Aebischer et al. 1993), so there were some concerns in using the Neu method (Neu et al. 1974). This constraint was ultimately considered acceptable though following a comparison of selection analysis methods conducted by McClean et al. (1998). The authors found that the Neu method was the only method that identified selection patterns consistent with known requirements and did so across several spatial scales. Although this limitation should be considered when interpreting and applying habitat selection results, consistency across spatial scales and between nest sites and BAs reinforce those classes that appear to be most important.

Another problem in interpreting these results is that there is not necessarily a causal effect. As indicated in the model, distance to water appears to be the key factor in where bald eagles will nest. Preferred land cover classes most likely are not being selected but are simply characteristic of relatively undisturbed, lowland areas near water in the NLP. This may place more emphasis on those areas that are avoided or tend to occur in greater proportion in failed nests. These classes appear to be more consistent in both spatial and temporal patterns than those classes that are preferred. It may then be just as important to identify suitable areas based on a lack of these avoided classes near suitable water bodies, rather than trying to identify all combinations of classes that are preferred.

## MANAGEMENT IMPLICATIONS

In spite of these limitations, there are some useful trends in land cover patterns associated with nesting areas specifically in the NLP. More importantly, methods that were explored could also prove to be useful in the future. Whether the population experiences another dramatic decrease or continues expanding until usable habitat is saturated, a method for identifying suitable nesting areas will be a useful tool in management as land conversion continues to occur. The use of BAs rather than individual nest sites adds the component of considering all nests associated with a bald eagle breeding pair, and removes the dependency between activity / inactivity among associated nests. This allows consideration of bald eagle breeding habitat variables beyond an actively defended nest. The method used for delineating BAs is by no means the best possible, but it can be viewed as a starting point. The results of BA analyses are difficult to interpret because of different land classification schemes. However, this method offers addition of a spatial component to BAs rather than just using active nests to identify habitat use by breeding bald eagles.

Although based on individual nest sites, the models developed for this study can also provide direction in nest habitat identification. However, it is not recommended that any particular model be applied at this time. This process was based on 1993 data and cannot be accurately attributed to present conditions. Instead, the information gained from these models should be seen as a test of a method that can be performed efficiently while still providing sufficiently accurate results. Using only land cover classification and distance to water correctly identified approximately 80% of existing nests. This is comparable to other nesting habitat models based on variables typically require site visits and field data collection (Bowerman 1993, Livingston et al. 1990).

Overall, a logistic regression model based on land use / cover data can provide an accurate means of identifying bald eagle nesting habitat over a large geographic extent, while focusing on land cover particular to the region. However, to use this method in Michigan, it is recommended that a model be constructed based on the newer land cover data that is due for release. Using BA land cover instead of nests to develop the model would also more adequately take into account inactive BAs and maintain an independent sample. A more recent model coupled with a nesting population that is nearing habitat saturation, should provide a better measure of what is currently happening and provide better results in identifying remaining suitable habitat.

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APPENDIX I

Metadata for Michigan Bald Eagle Nest Locations - Digital Point File

**Title:** mi_benests

**Format:** ArcView 3.2 shapefile and all associated files ( *.shp, *.dbf, *.shx)

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**Created:** 2002

**Description:** Digital point file of all reported bald eagle nests in Michigan with locational information (excluding Isle Royale). Attributes include coordinate location when available, Public Land Survey description (PLS) and other information related to specific nest sites.

**Spatial Reference:** Michigan GeoRef from Oblique Mercator projection
Scale factor at center = 0.9996
Azimuthal angle = 337.25556
False easting = 2546731.496
False northing = - 4354009.816
Horizontal datum name = North American Datum 1983 (NAD83).

**Map Units:** meters

**Contact:**

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**Methods:**

Nests with coordinate locations

Nests with coordinate locations were digitized by adding an event theme in ArcView, referenced to the decimal degree latitude / longitude coordinates, and converting the theme to a shapefile. It was assumed that these coordinates had been taken in the WGS 1984 datum since that is the default setting for most GPS units. Some coordinate locations were extrapolated from paper maps, but since the source map data were not available, there were relatively few locations derived by this method (~5) and WGS 1984 matches closely to NAD 1983, those locations were treated the same as GPS locations. The datum for this shapefile was converted using the ESRI Projection Utility, to convert from geographic lat/long WGS 1984 to geographic lat/long NAD 1983. The shapefile was not projected at this time – only a datum conversion was performed using a geographic transformation of WGS 1984 (1) to NAD 1983. The NAD 1983 shapefile was added to a view in ArcView and projected to Michigan GeoRef using the MI DNR Projection Extension (Michigan Department of Natural Resources).

Nests previously digitized

Some nests had been previously digitized in CMAP using approximately the same methods as mentioned above (J. Stuht 2000). These files (three regions – UP, NLP and SLP) were converted to ArcView shapefiles by J. Wilson (USFWS, East Lansing, Michigan), from whom they were obtained. The shapefiles, all in NAD 1927, were converted individually to Michigan GeoRef using the MI DNR Projection Extension. The resulting regional GeoRef files were merged to form a statewide file. The attribute table for this file was linked to the coordinate location file, and a series of selections and queries were used to determine which nests in the Stuht file were already in the coordinate location file. These nests were removed from the Stuht file to allow the most recent coordinates to take precedence (aerial GPS is updated by ground GPS when possible). The remaining nests from the Stuht file were merged with the coordinate location file.

Nests not previously digitized

The original location source spreadsheet (D. Best, USFWS, East Lansing) was reorganized as a flat file in *.dbf format, and imported to ArcView. It was linked to the attribute table from the nests already digitized to determine the remaining nests that had only a PLS description and had not been part of the Stuht file. These were digitized manually in ArcView, directly in Michigan GeoRef, using PLS township / range, section and subsection grids. For each nest, a point was placed at the center of the smallest PLS unit provided. In some cases, if other information was provided in the original location spreadsheet, Michigan Resource Inventory System (MIRIS) base maps (roads, hydrology and land use / land cover) were added to the view to gain more accurate placement. The base maps were created in 1978, so were used only when there was reference to features that are relatively unchanging (i.e., N of river, 100m from shoreline). Once completed, the manually digitized nest file was merged with the previous shapefile.

Final shapefile

XY coordinate fields (in Michigan GeoRef coordinates) were added to the shapefile .dbf using the ArcView extension Coordinate Tool Box Ext. 1.0 (www.esri.com). This was done by setting the view properties map and distance units to meters, then using the extension tool "Add XY coordinates in decimal degrees" to add coordinates in decimal format. All fields except Nest_Site, X_Coord and Y_Coord were removed to allow replacement by the corrected source spreadsheet (see Data Quality). The final corrected spreadsheet was converted to .dbf format, imported to ArcView and joined by Nest_Site to the digital shapefile attribute table. The joined table was exported as a new .dbf and used to add a new event theme in ArcView using the Michigan GeoRef XY coordinates. This was converted to a shapefile to produce the final digital location file with complete and corrected attributes. The GeoRef was reprojected to Geographic NAD 1983 to add fields for latitude and longitude based on the digitized position of nests. These fields were also added to the GeoRef shapefile.

**Data Quality:**

All coordinate locations were checked against PLS locations to eliminate original data entry errors. If any GPS locations did not agree with the recorded PLS position, PLS descriptions took precedence. Usually this was only a matter of the GPS being in an adjacent subsection, and the point was nudged across the line. In cases where the GPS was believed to be more accurate based on additional information, the PLS description was modified in the attribute table.

Nests points taken from a Stuht file were also checked against PLS grids to detect any locational shifts that may have occurred during re-projection, or conversion from CMAP to ArcView. Nests that were not centered, but still in the smallest legal unit provided were not re-centered. This was based on the assumption that there was a paper map showing nest location used in the initial digitizing. A small number of nests (~ 5) occurred in a different subsection than what was reported in the source data. These were assumed to have been near a subsection line originally and shifted during re-projection. These were nudged back across the line, but not centered.

The next check was performed by querying nests by county, to confirm that all locations fell within the county boundaries for which they were reported. Discrepancies were noted, discussed with D. Best and corrected.

Nests were also checked against 1:24,000 great lakes shoreline base maps (MDNR) and 1:100,000 base hydrology (polygon, USGS). Nests that fell offshore or in inland lakes were moved if it was possible to keep them within the same PLS location. In some cases, nests were not moved because locations occurred in wetland areas that were digitized as part of a lake in the hydrology base maps.

**Note**: Nests were placed as accurately as possible according to the recorded location. Some may or may not fall within a lake depending on the accuracy and resolution of base maps used (for example, not all base maps include smaller islands or delineation between lake and swamp). This should be taken into consideration when conducting analysis.

Nests associated with Michigan breeding areas, but actually located in Wisconsin have PLS reported in Wisconsin township / range. For example, a nest in a Menominee County breeding area but across the state line has a reported range of "East" while other nests in Menominee County have reported ranges of "West". This is not an error, and should be read according to a Wisconsin PLS grid rather than Michigan.

All discrepancies that were found either in coordinate locations or PLS were reported to D. Best. Once the correct information was determined, the nest was re-positioned in the digital file, and the information in the source data spreadsheet was corrected. The corrected spreadsheet was used as the final source .dbf mentioned above to create the final shapefile.

Final digital shapefile:

1659 nests
593 breeding areas

Not digitized:

17 nests did not have enough information to be placed
Isle Royale nests are not included
Nests in Wisconsin or Canada breeding areas with no Michigan breeding area designation were not included

**Data Accuracy:**

PLS locations were considered most accurate when there were discrepancies between GPS and PLS. If GPS coordinates did not agree with other information, PLS and referential information took precedence.

PLS: Nests without GPS readings were digitized according to PLS and any other locational information provided. When no additional reference was available, such as distance from a river, the nest was placed at the center of the smallest unit in the PLS description. The greatest possible error would then occur for a nest that is actually at the corner of the smallest unit recorded, as follows:
Section – 0.7 miles (1126.5 meters)
¼ section – 0.35 miles (563.2 meters)
¼ ¼ section – 0.18 miles (289.7 meters)

Ground GPS: Nests with ground coordinates reported had GPS readings taken at the nest tree and are accurate within a few meters. Those taken before 2000 when selective availability was turned off were not always corrected and may be approximately 200-300 meters off.

Aerial GPS: Aerial GPS readings were taken while circling a nest at approximately 100 meters, however aerial readings taken before 2000 were not always corrected. Due to the readings being taken in flight and selective availability, readings before 2000 may be up to 0.5 miles (805 meters) off. However, when these nests were checked against PLS descriptions, most fell at least within the correct ¼ section reported. Manual replacement of aerial GPS positioned nests was usually due to the coordinates placing them in a body of water, rather than on shore.

## APPENDIX II

MIRIS land cover classes occurring in Black River Watershed bald eagle nests and grouped classes used in resource selection analysis

| MIRIS level 1 | MIRIS level 2 | MIRIS level 3 | MIRIS level 4 | Resource Selection Groups |
|---|---|---|---|---|
| Urban | Residential | Single family, duplex | | Urban |
| Urban | Extractive | Wells | | |
| Agriculture | Cropland | | | Agriculture |
| Non-forested | Herbaceous | | | Non-forested |
| Non-forested | Shrub | | | |
| Forested | Broadleaved | Northern hardwood | Mixed | Mixed northern hardwood |
| Forested | Broadleaved | Northern hardwood | Sugar maple | N. hardwood - sugar maple |
| Forested | Broadleaved | Oak/hickory | Red oak | Red oak |
| Forested | Broadleaved | Aspen, white birch and associates | Mixed | Mixed aspen / white birch |
| Forested | Broadleaved | Aspen, white birch and associates | Bigtooth aspen | Bigtooth aspen |
| Forested | Broadleaved | Lowland hardwood | Mixed | Mixed lowland hardwood |
| Forested | Broadleaved | Lowland hardwood | Soft maple | Low. hardwood - soft maple |
| Forested | Broadleaved | Lowland hardwood | Aspen | Low. hardwood - aspen |
| Forested | Broadleaved | Lowland hardwood | Other | Low. hardwood - other |
| Forested | Coniferous | Pine | Mixed | Mixed pine |
| Forested | Coniferous | Pine | Red pine | Red pine |
| Forested | Coniferous | Pine | Jack pine | Jack pine |
| Forested | Coniferous | Other upland conifers | White spruce | Upland conifer - white spruce |
| Forested | Coniferous | Lowland conifer | Mixed | Mixed lowland conifer |
| Forested | Coniferous | Lowland conifer | Cedar | Cedar |
| Water | Stream | | | Water |
| Water | Lake | | | |
| Water | Reservoir | | | |
| Wetland | Forested | Wooded wetland | | Wetlands |
| Wetland | Forested | Scrub,shrub wetland | | |
| Wetland | Non-forested | Aquatic bed | | |
| Wetland | Non-forested | Emergent | | |