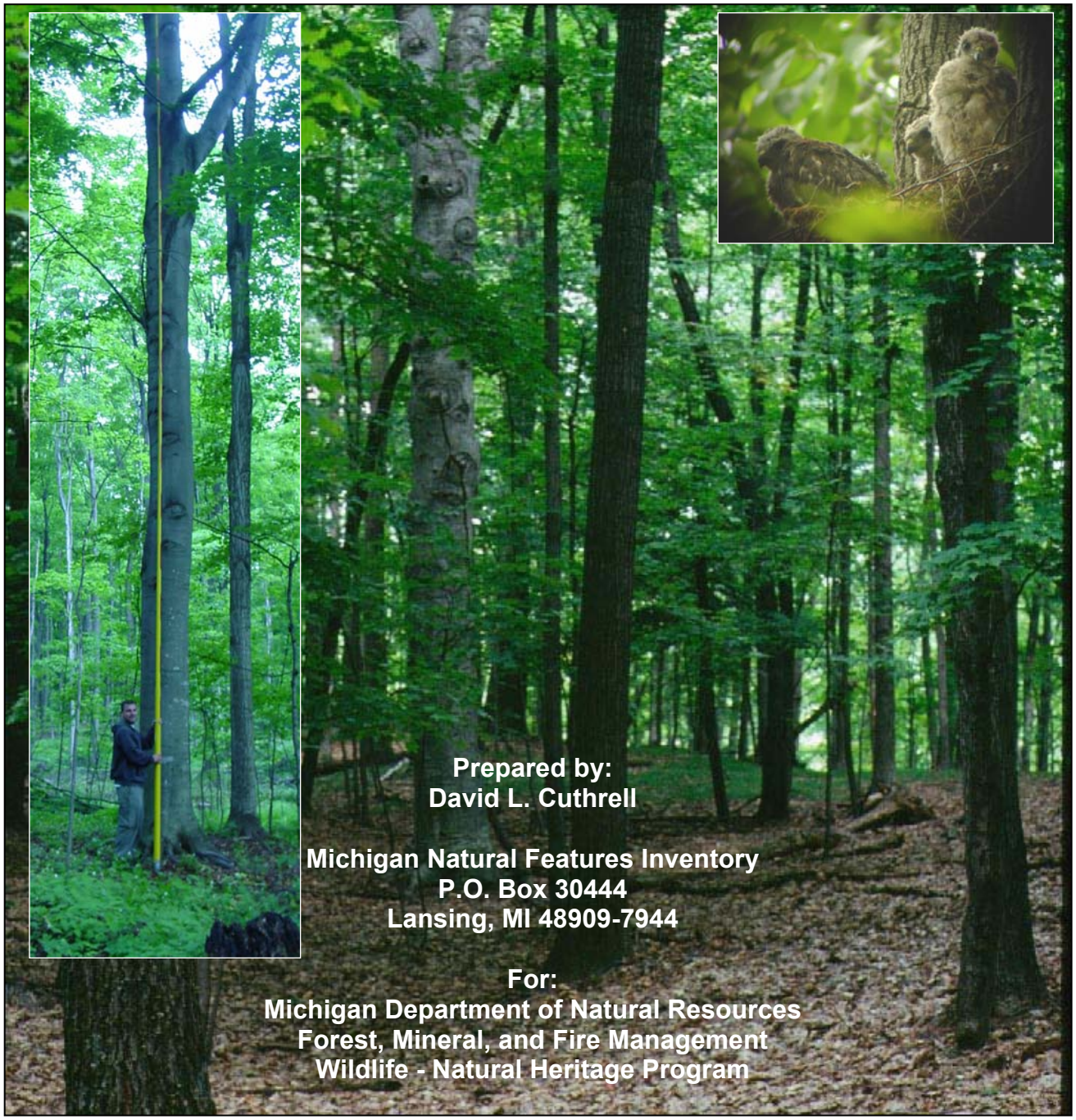
Red-shouldered Hawk Productivity, Landscape Analysis, and Nest Site Selection on State Forest Lands in Northern Michigan (1998-2003)



Prepared by:
David L. Cuthrell

Michigan Natural Features Inventory
P.O. Box 30444
Lansing, MI 48909-7944

For:
Michigan Department of Natural Resources
Forest, Mineral, and Fire Management
Wildlife - Natural Heritage Program

Report Number 2003-13
September 30, 2003

TABLE OF CONTENTS

LISTS OF TABLES

LISTS OF APPENDICES

ABSTRACT

In the early part of the 20th century the Red-shouldered Hawk (*Buteo lineatus*) was a common bird in southern Michigan. Since then its breeding range may have shifted from southern Michigan to the Northern Lower Peninsula (NLP). Currently the Red-shouldered Hawk is listed as state threatened in Michigan. We conducted systematic surveys for the Red-shouldered Hawk in nine state forest areas (Atlanta, Escanaba, Pigeon River, Indian River, Gaylord, Traverse City, Gladwin, Newberry, and Naubinway). A total of 139 compartments were intensively surveyed during a six-year period (1998 – 2003). Nest productivity surveys were also conducted over a five-year period to assess the reproductive success of populations in Michigan's NLP. Nearly 280 nests were assessed for nest productivity measures such as, nest-site fidelity, nest success, average brood size, and nest predation rates. Earlier research also analyzed habitat at the landscape, local site, and nest tree levels for nest sites and random points.

For areas surveyed over the four-year study period, we found that nesting territories had a high re-occupancy rate (78%). Further, territories tended to be evenly distributed in areas that contained large contiguous tracts of suitable habitat with a nest every 1.5 km ($\pm$ 0.26 km). Nest productivity during this study tended on average to be high (66% successful nests) and brood size averaged 2.07 young per successful nest. Nest predation rates were fairly low with 15% of nests being depredated.

Our habitat analysis indicated that nests typically were located within a heavily forested landscape (71% forest cover $\pm$ 3%), primarily composed of upland deciduous forests (53% upland deciduous forest cover $\pm$ 6%). Nests were typically located in northern hardwood stands with well-stocked pole or saw timber (90.2% of all nests documented). Nests also tended to be located near wetlands (80% within 0.4 km) and upland openings (mean distance to upland opening 181 m $\pm$ 46 m).

Our earlier data indicate that nest trees tended to be deciduous, primarily beech, however any tree with adequate structure, i.e., a multi-pronged crotch, could be suitable. Nests tended to be placed in large, mature, super-canopy trees and the nest itself was placed on average 14.1 m $\pm$ 0.37 m above the ground. At the local site level, canopy height, basal area, tree density, canopy closure, and average tree diameter at breast height (dbh) appear important in nest selection. By utilizing both a landscape and nest site approach, insight on distribution and habitat use can be gained which will facilitate sound management of this species. Information from this study is also being used to assess abundance and distribution, which will help determine the appropriate state listing status for this raptor species. This project, however, did not address the assessment of management impacts on Red-shouldered Hawks.

INTRODUCTION

The Red-shouldered Hawk (*Buteo lineatus*) is currently listed as a state threatened species in Michigan. Historically it was considered one of the most common diurnal raptors in the Southern Lower Peninsula (SLP) (Barrows 1912). However, by the mid-1900's this species had become uncommon in southern Michigan. Population declines have been primarily attributed to loss of forest and wetland habitats. Presumably, as a result of habitat loss, populations shifted their breeding range from southern Michigan to the more forested portions of the state in the Northern Lower Peninsula (NLP) (Brewer et al. 1991). Currently, there are two primary sources of distributional information concerning this species in Michigan. These include the Breeding Bird Atlas with 119 confirmed nests documented during the 1980's (Brewer et al. 1991), and the Michigan Natural Features Inventory's Biological Conservation Database with ~ 300 confirmed nests documented since the early 1980's (Natural Heritage Biological and Conservation Data System 2003). Distributional patterns from each of these databases mirror each other rather closely. Two distinct population clusters were evident from the earlier data, one centered in the NLP, including Emmet and Cheboygan counties, and the other centered in the Manistee County area. These population clusters were likely a result of survey effort by USFS and others such as Ebbers work in the late 1980's. Only scattered occurrences of confirmed Red-shouldered Hawk nests occur in the SLP and the Upper Peninsula.

This species is a woodland raptor that requires forested landscapes composed of deciduous or mixed forests. The proto-typical habitat for this species is mature forested floodplains (Johnsgard 1990). Upland hardwood systems are also utilized when wetland complexes are juxtaposed or interspersed among them (Craighead and Craighead 1969, Postupalsky 1980, Bednarz and Dinsmore 1981, Cooper and Cuthrell 2000). In Michigan this species has been most frequently documented in hardwood stands composed of well stocked pole or saw timber, particularly hardwood complexes with associated wetland habitats. Hawks have also been documented in older aspen stands (A6/9), lowland poplar stands (P6), cedar swamps (C6/9), lowland conifers (Q6/9), and occasionally in pine communities (W8/9) (Cooper et al. 1999). Red-shouldered Hawks are strongly associated with wetlands and the core of a breeding pair's territory typically encompasses wetland habitat. Wetlands such as beaver ponds, wet meadows, and lowland forests are utilized primarily for foraging purposes (Howell and Chapman 1997). Small upland openings are also used to some extent for foraging habitat (Evers 1994). Red-shouldered Hawks typically nest in stands of timber with greater than 70% canopy closure (Bryant 1986) and relatively open understories (Evers 1994). Nests are most frequently placed high (usually just below the canopy) in mature deciduous trees and within close proximity of wetland habitat (Titus and Mosher 1981, Woodfry 1986, Ebbers 1986, Cooper et al. 1999). Mature maple, beech, birch, and aspen are frequently used nest trees in Michigan (Ebbers 1989, Cooper et al. 1999). However, any tree species with the appropriate structure (i.e., a multi-pronged crotch just below the canopy) can be utilized.

Purpose of the Study

Currently, there is a lack of information on this species' distribution and productivity in Michigan, including state forest lands. In addition, the impacts of forest management practices on habitat use and nest productivity have not been evaluated. This project entails systematic surveys on state forest lands, reconfirmation of historical nest sites, and monitoring productivity on a representative subset of nest sites in each

state forest. Information gathered from surveys and nest monitoring will be used to identify core areas of nest site concentrations on state forest lands, identify areas that support long-term population viability, and facilitate development of management guidelines. Further, this project, coupled with other related inventories (e.g., Red-shouldered Hawk inventories on state parks lands, natural areas, national forest lands, and state game areas) should facilitate assessment of the appropriate state listing status. This report focuses on six years of data and includes an assessment of territorial re-occupancy, nest site re-occupancy, and nest productivity. This project, however, did not address the assessment of management impacts on Red-shouldered Hawks.

METHODS

Establishment of Calling Stations

Surveys were conducted from early April to mid-May of 1998 - 2003. High priority forest compartments at the Pigeon River Country (PRC) Forest Management Unit, the Indian River (IR) area of the Gaylord Forest Management Unit, the Gaylord South Management Unit (GA), and the Traverse City Forest Management Unit (TC) were intensively surveyed for Red-shouldered Hawks. In addition, portions of high priority forest compartments in the Atlanta (ATL), Escanaba (ESC), Gladwin Forest Management Unit (GL), Naubinway Forest Management Unit (NA) and Newberry Forest Management Unit (NE) were surveyed for Red-shouldered Hawks. Large deciduous or mixed forest complexes composed of medium to well stocked pole or saw timber (stocking density 5/6, or 8/9) with wetland habitats juxtaposed or interspersed among them were targeted for surveys. Also, select coniferous forest communities, both wetland and upland, that had a deciduous component and associated wetland habitat were surveyed as well (see Appendix I for cover types surveyed). These types of forest/wetland complexes were delineated by analyzing forest operational inventory (OI) maps, USGS topographical maps, 1978 current land cover maps, 1998 air photos, and by consulting with Michigan Department of Natural Resources (MDNR) Forest, Mineral and Fire Management (FMFM) and Wildlife personnel. Transects were placed every ¼ mile through forest habitats within compartments selected for surveys. Along each respective transect a calling station was placed every ¼ mile. At each calling station a taped conspecific Red-shouldered Hawk call was broadcast with a predator caller three times: at 60 degrees for 10 seconds, 180 degrees for 10 seconds, and 300 degrees for 10 seconds. This was followed by 30 seconds of listening. This calling sequence was repeated three times at each calling station. When hawks responded to the taped calls, observers intensively searched for birds and/or a nest in the direction the call was initially heard (Kennedy and Stahlecker 1993, Bowerman pers. comm.). In addition, 2-3 random calling stations were established per compartment surveyed and the same calling sequence mentioned above was utilized. Random calling stations were added to surveys during 1999-2001 for future statistical comparisons in order to differentiate habitat patterns around nest sites from habitat patterns that occur throughout the larger landscape (Moritz, pers. comm.). Currently, over 100 random points have been surveyed in northern Michigan forest areas. Raptor nest reporting forms (Appendix II) were filled out at each survey site and random point. Confirmed nest locations from 2002-03 were recorded using Garmin GPS units. Nest locations were then loaded into Arc View and records were transcribed and entered into the Michigan Natural Features Inventory's Biological Conservation Database.

Productivity Surveys

During early to mid-June of 1998 - 2003, a representative subset of active nests was re-visited at least once to assess productivity. Only those nests where

incubation was confirmed during April surveys were considered active. Surveys were timed during the later part of nestling stage, usually within a couple weeks of fledging, because young birds are more conspicuous at this time. Two methods were used to assess productivity. These included on-the-ground surveys where the nest is observed from a vantage point or the base of the nest tree is inspected for white wash. A second more definitive method was looking into the nest with a mirror attached to a 15 m (50 ft) pole. A nest was considered successful if at least one young 80% of the fledgling age was produced (Kochert 1986).

Habitat Features

Landscape Level Attributes

Habitat data around nest locations documented at the PRC and IR were summarized by utilization of 1998 air photos, OI maps, USGS topographical maps, 1978 current land cover maps, and some limited ground truthing. The percentage of nests occurring in the following categories was calculated: cover type (OI designations), location in upland or lowland, proximity to wetland, distance to nearest upland opening, and stocking density/size class (OI designations). The percent cover of habitat types (Table 1) around nest sites (n=51) and random points (n=48) were calculated by centering the nest site within a 1.8 km x 1.8 km (1 mi x1mi) quadrat (Ebbers 1989, Bowerman pers. comm.). The percent cover of each habitat type was estimated by laying a film transparency grid over the quadrat and counting the number of intersects per habitat type within the grid. The number of intersects per habitat type was divided by the total number of intersects per grid (n = 361) to calculate percent cover per nest site and random point. Percent cover for nest sites and random points were expressed as a mean percent and 95% confidence intervals for each mean percent were calculated as well. Each respective cover type was delineated by utilizing 1998 air photos and OI maps. Distance to wetland habitat and upland openings were measured in the field by pacing if distances were less than 200 m. If distances were greater than 200 m, measurements were derived from 1998 air photos by utilizing a parallax wedge. Landscape scale data are still being analyzed for nests located in the five other state forest areas.

Table 1. Description of landscape-level attributes.

Variable	Definition
% Forest	Forest cover included deciduous or coniferous cover that was composed of pole or saw timber
% Open	Open area included grassland, seedling stands, clear-cuts, lowland brush, upland brush, and open water
% Upland Deciduous Forest	Upland deciduous forest included all forest communities dominated (> 50%) by deciduous trees in upland habitat
% Wetland Deciduous Forest	Wetland deciduous forest included all forest communities dominated (> 50%) by deciduous trees in wet habitat
% Upland Conifer Forest	Upland conifer forest included all forest communities dominated (> 50%) by coniferous trees in upland habitat
% Lowland Conifer Forest	Lowland conifer forest included all forest communities dominated (> 50%) by coniferous trees in wetland habitat
% Open Water	Open water included lakes, ponds, and impoundments of water
% Wetland Opening	Wetland openings included marsh and lowland brush

Nest Site Variables

Various habitat attributes were summarized during August 2000 and August 2001 for 44 nest sites and 35 random points by centering the nest site in a 0.04 ha (1/10 ac.) plot (Trexel et al. 1999). These variables included:

1) **Nest tree diameter breast height (DBH):** Diameter (cm) at breast height of nest tree.
2) **Nest tree height:** Height (m) of the nest tree estimated by use of a clinometer.
3) **Nest percentage:** Nest height/tree height X 100.
4) **Canopy height:** Mean height, from the forest floor to the lower portion of the canopy, from five randomly chosen trees within plot.
5) **Canopy closure:** The percentage of the area over the plot occluded by overstory foliage, measured by 40 ocular tube readings.
6) **Ground cover:** The percentage of the ground covered by ground-layer foliage. This was measured by systematically placing 10 sampling points radiating from the nest tree in each of the four cardinal directions. Ground cover was measured by placing a meter stick vertically to the ground every meter along the transect line. When vegetation contacted the front edge of the stick it was counted as a hit. Total ground cover was calculated as the total number of hits/total number of points X 100.
7) **Sapling density:** The number of woody stems greater than shoulder height and less that 12.7 cm DBH and contained within ½ of the 0.04ha plot.
8) **Shrub density:** The number of low shrubs < 12.7 cm DBH and shorter than shoulder height contained within ¼ of the plot.
9) **Tree density:** The number of trees $\geq$ 15 cm DBH per 0.04 ha plot.
10) **Basal area:** m^2/ha trees.
11) **Mean DBH:** Mean DBH (cm) of trees in study plot.

RESULTS AND DISCUSSION

A total of 41 PRC, 25 IR, 16 GA, 9 TC, 15 GL, 12 NA, 4 NE, 8 ATL, and 9 ESC compartments (139 total) were systematically surveyed during 1998 – 2003 (Appendix I). In addition, over 100 random points were surveyed in compartments that were systematically surveyed. The majority of compartments containing high quality habitat (i.e., large deciduous or mixed, pole/saw timber complexes juxtaposed or interspersed with wetland habitat) in the PRC, IR, GA, TC, and GL areas have been surveyed at least one time. Since the amount of suitable habitat within each compartment varied, some compartments were more intensively surveyed than others. Further, a wide range of cover types of varying stocking densities were intensively surveyed for Red-shouldered Hawks (Appendix I). Varying landscape positions, such as very dry upland forest (up to a mile from wetland habitat) and wet lowland forest, were systematically surveyed as well. A few habitat types were under represented during surveys and these included red pine stands, white pine stands, and lowland conifers (Q and C types). These habitat types are not typically exploited by Red-shouldered Hawks for nesting purposes (Johnsgard 1990). However, lowland conifer and white pine stands with a deciduous tree component, provide good nesting habitat for Red-shouldered Hawks in other portions of their range (J. Cooper, personal communication). Therefore, these habitats need to be more intensively surveyed in the future.

Territory Activity

A total of 38 active territories (i.e., area where hawks were heard or had a freshly tended nest) were documented during 1998, 105 active territories during 1999, 80 active territories during 2000, 79 territories during 2001, 92 during 2002 surveys, and 95 during 2003 surveys (Table 2). Among theses active territories, 20 active nests (i.e., where incubation was confirmed) were located during 1998, 34 during 1999, 35 during 2000, 56 during 2001, 64 during 2002, and 70 during 2003, for a total of 279 nests

Territorial re-occupancy (i.e., territories occupied during successive years) was high among all forest areas. The overall re-occupancy rate of territories during successive years of the study has been high at 78% (Table 2). Jacobs and Jacobs (1997) reported that an 83% re-occupancy rate (range of 53% - 83%) was the highest they have documented in Wisconsin between the years of 1992 – 1997. The percentage of territories re-occupied between 1998 and 2003 in Northern Michigan forest management units compares rather well to the high re-occupancy rate documented by Jacobs and Jacobs (1997).

Nest site fidelity, which occurs when a pair utilizes the same nest as the previous year, was high as well during 1999-2003. Fifty percent of the nests utilized in each forest area during 1998 were re-occupied during 1999, 60% of nests utilized during 1999 were used as nest structures in 2000, and 67% of nests used during 2000 were used again in 2001, 71% of nests used in 2001 were used again in 2002 for a four year average of 64%. Johnsgard (1990) felt that a nest re-occupancy rate of 37%, which was documented by Jacobs et al. (1988) in Wisconsin, was high. Dijak et al. (1990) in Missouri found a 35% re-occupancy of nests in successive years, which is similar to the rate reported in Wisconsin. Nest site fidelity in Michigan state forests clearly exceeds rates documented in Wisconsin and Missouri.

At the PRC, known active nest sites were distributed rather evenly throughout large contiguous hardwood/wetland complexes during 1999. The average distance between nests within these complexes was 1.5 km $\pm$ 0.26 km (0.93 mi $\pm$ 0.16 mi). In large contiguous areas of suitable habitat in Maryland and Georgia, the average distance between nest sites was 2.1 km and 2.0 km, respectively (Stewart 1949, Howell and Chapman 1997). Uniform nest site spacing is a phenomenon that typically happens in large contiguous areas of suitable nesting habitat in order to abate territorial overlap, thus reducing interference in breeding and hunting among pairs (Howell and Chapman 1997). This phenomenon was evident in the PRC during this study, which suggests that large areas of the PRC Forest Management Unit offer suitable nesting habitat for the Red-shouldered Hawk, provided sufficient prey base is available in a given year. Uniform nest spacing at the other state forest areas was not as apparent (however data analysis is still being conducted). This could be attributed to differences in landscape composition. Also, fragmented ownership patterns did not allow entire forest complexes to be surveyed due to private in-holdings.

Table 2. Red-shouldered Hawk reproduction 1998-2003 at nine northern Michigan state forests.

Reproductive Variable	1998	1999	2000	2001	2002	2003	Study Average
Number of sites visited	38	105	80	79	92	95	82
Number of occupied sites	-	21	42	47	59	72	48
Number of active nests located	20	34	35	56	64	70	47
Re-occupancy rates	-	78%	81%	78%	75%	77%	78%
Number of successful nests	13	28	24	39	44	42	32
Percentage of successful nests	65%	82%	69%	70%	60%	60%	66%
Number of young fledged	-	26 (11)	25 (12)	70 (33)	71	92	57
Young/Successful nest	-	2.36	2.08	2.12	1.61	2.19	2.07
Young/Active nest	-	-	-	1.25	0.97	1.31	1.18
Predation Rates	20%	12%	29%	11%	7%	10%	15%

Productivity

The fate of 279 active Red-shouldered Hawk nests were followed over the duration of this study. Nest productivity among northern Michigan forest areas surveyed was high (66% successful) (Table 3). Average brood size (number of young per successful nest), from nest site data combined for all forest areas between the years of 1998 - 2003 was 2.07 young per successful nest (Table 3). Nest predation was confirmed (e.g., claw marks on trees, den tree nearby, nests torn apart, remains of adult hawk, etc.) for 15% of occupied nests between 1998 – 2003 (Table 3). The primary nest predator implicated was the raccoon (*Procyon lotor*) and great-horned owl (*Bubo virginianus*). Five adult Red-shouldered Hawks were killed during 2000 and 5 were killed during 2001 on or near the nest. These deaths were most likely the result of predation by great-horned owls. Jacobs and Jacobs (1997) and Ebbers (1989) also documented the raccoon and great-horned owl as primary predators of Red-shouldered Hawks in Wisconsin and Michigan, respectively.

Nest success rates were high over the past four years and compare rather favorably with other studies concerning this species (Table 4). However, wide variations in nesting success rates can occur annually (Jacobs and Jacobs 1997, Stavers et al. 1995, and Henny et al. 1973). Monitoring of nest success rates at all forest areas only spans a five-year period and varied somewhat between years. Therefore, in order to fully assess population viability at northern Michigan state forest areas, monitoring will need to continue over the next several years. Henny et al. (1973) felt that a recruitment rate of 1.95 young per active nest with at least 77% of all nesting attempts being successful was needed to replace annual mortality. Jacobs and Jacobs (1998) argued that Henny's model was biased too high due to a small sample size and large variation in the range of recruitment rates among years. Jacobs and Jacobs (1998) analyzed productivity data from Wisconsin using a computer population model (PD: Population Dynamics Modeling, Version 4.0 C 1989 by J.W. Grier, Zoology Dept. ND State Univ., Fargo, ND). From this model they estimated that a recruitment rate of 1.4 young per active nest with over 50% of nesting attempts being successful was needed to replace annual mortality (Jacobs pers. comm.). Recruitment rates

Table 3. Productivity and Predation rates by northern Michigan forest management unit 1998-2003.

Reproductive Variable	Pigeon River	Indian River	Gaylord	Traverse City	Gladwin	Eastern UP[a]	Atlanta	Escanaba	Overall 1998-2003
Percentage of Successful Nests [1]	70/107 65%	40/57 70%	26/38 68%	28/43 65%	6/9 66%	12/16 75%	7/14 50%	1/3 33%	190/287 66%
Number of Young per Successful Nest [2]	1.98	2.30	2.05	2.00	2.00	2.00	2.00	2.00	2.07
Number of Young Per Active Nest[3]	1.19	**1.50**	1.10	1.23	**1.78**	**1.62**	1.00	0.67	1.18
Predation Rates [4]	16%	14%	13%	12%	0%	0%	8%	0%	15%

[a] Includes both Naubinway and Newberry State Forest Management Units.

[1] The percentage of nests with $\geq$ 1 young produced to 80% of the fledgling age (4 – 4.5 weeks old)

[2] The average number of nestlings 80% of the fledgling age per successful nest

[3] The average number of nestlings 80% of the fledgling age per active nest (this number is conservative as we did not climb the nest tree)

[4] The percentage of nests that were destroyed by a nest predator

Table 4. Comparison of Red-shouldered Hawk nest success rate at seven northern Michigan state forest areas with other regional studies.

Location	No. Nests Studied	% of Nests Successful	No. Young Fledged / Active Nest	Source or Researcher
Iowa (1979)	8	88	2.90	Bednarz 1979
Southern Ontario (1982)	6	83	1.80	Armstrong and Euler 1982
Southern Michigan (1942,47,48)	61	-	1.80	Craighead and Craighead 1969
Western Maryland (1982)	17	53	1.80	Janik and Mosher 1982
Northern Michigan (1986-88)	29	79	2.20	Ebbers 1989
Central Maryland (1943,49,60-71)	74	68	1.58	Henny et al. 1973
Eastern Iowa (1983-94)	60	-	1.52	Stravers 1995
Jacob's Recruitment Rate	**-**	**50**	**1.40**	**Jacobs 1999**
Southern California (1973)	29	66	1.34	Wiley 1975
Northern Michigan (2003)	70	60	1.31	Cuthrell 2003
Northern Michigan (2001)	56	70	1.25	Cuthrell and Cooper 2001
Northern Michigan (1986-88)	44	57	1.20	Ebbers 1989
Northern Michigan (1998-2003)	190	68	1.18	**This report**
Central and NE Wisconsin (1990-99)	557	51	1.13	Jacobs and Jacobs 2000
Northern Michigan (2002)	64	60	0.97	Cuthrell 2002

throughout this study were lower than the model, however nest success during this study was much higher than Jacobs and Jacobs model.

The results from this study are similar to results obtained by Ebbers (1989) who documented a moderate nest success rate (56.8% nest success) and low numbers of young produced per active nest (1.2 young per active nest). In fact, Ebbers felt that the Red-shouldered Hawk population in the Straits region functioned as a population "sink" (i.e., annual mortality was greater than annual recruitment) and that the population in the Manistee County area functioned as a "source" population (annual recruitment was greater than annual mortality). Nest success rates were high over the past six years and compare rather favorably with other studies concerning this species. However, wide variations in nesting success rates can occur annually (Jacobs and Jacobs 1997 and Henny et al. 1973). Monitoring of nest success rates at all forest areas only spans a six year period and varied somewhat between years. Therefore, in order to fully assess population viability at northern Michigan state forest areas, monitoring will need to continue over the next several years. Monitoring of nest sites is tentatively planned through the 2004 season.

Other reasons for different estimates of nest success and recruitment rates between this study and Ebbers' study include differences in survey methodology, maturation of forests, changing habitat structure, differences in sample sizes between studies (Table 4), and changes in the abundance of nest predators/competitors in the region. Continued monitoring of productivity over a period of several years within each forest area will provide a data set which should reveal factors that limit or enhance nest productivity.

Habitat Features

One of the objectives of this study was to determine if Red-shouldered Hawks use select portions of the landscape for nesting habitat. Varying cover types (e.g., open habitat, deciduous forest, coniferous forest, etc.) and landscape positions such as very dry upland forest (up to a mile from wetland habitat) and wet lowland forest were extensively and systematically surveyed among seven state forest areas over the past four years. A few habitat types were under represented during surveys including red pine stands, white pine stands, and lowland conifers (Q and C types). These habitat types are not believed to be typically exploited by Red-shouldered Hawks for nesting purposes (Johnsgard 1990). However, lowland conifer and white pine stands with a deciduous tree component could provide good nesting habitat for Red-shouldered Hawks. In addition over 100 random points among forest area compartments surveyed were sampled. No nest sites were found near random points (> 100 sampled). Occasionally a territorial bird responded to a conspecific call from a random point in habitat that was presumed to be inactive and not suitable for nesting. However, in virtually every case, observers followed the bird quite a distance from the random point into more "ideal" Red-shouldered Hawk habitat (e.g., deciduous/mixed forest near wetland habitat). These results indicate that Red-shouldered Hawks do not occur randomly on the landscape and that certain habitat attributes at the landscape and micro scales appear to influence selection of nesting habitat. Important attributes at both scales are discussed below.

Landscape Level Attributes

Analysis of landscape-level attributes revealed some interesting patterns around nest sites. Fifty-one nest sites and 48 random points were analyzed for landscape composition. The majority of the landscape surrounding both nest sites and random points was largely forested (71% $\pm$ 3% forest cover and 66% $\pm$ 5% forest cover, respectively) (Table 5). However, nest sites tended to be located in more heavily

Table 5. Landscape-level attributes around Red-shouldered Hawk nest sites at the Pigeon River Country (PRC) and Indian River (IR) forest areas (1998 – 2001).

Landscape Variable	Nest Sites	Random Points
% Forest	71% ± 3% (n=51)	66% ± 5% (n = 48)
% Open Habitat	29% ± 3% (n=51)	34% ± 5% (n = 48)
% Upland Forest	53% ± 6% (n=51)	45% ± 7% (n = 48)
% Wetland Deciduous Forest	3% ± 2% (n=51)	2% ± 1% (n = 48)
% Upland Conifer Forest	7% ± 3% (n=51)	11% ± 4% (n = 48)
% Upland Opening	24% ± 1% (n=51)	27% ± 4% (n = 48)
% Lowland Conifer	8% ± 3% (n=51)	8% ± 2% (n = 48)
% Open Water	2% ± 2% (n=51)	1% ± 1% (n = 48)
% Wetland Opening	3% ± 1% (n=51)	6% ± 3% (n = 48)
Cover Type[1]	Northern Hardwoods - 79.3% (n = 82)	Northern Hardwoods - 26.5% (n = 48)
	Oak - 3.7% (n=82)	Oak - 4.1% (n = 48)
	Aspen - 6.1% (n=82)	Aspen - 43% (n = 48)
	White Pine - 2.4% (n=82)	White Pine - 4.1% (n = 48)
	Birch - 2.4% (n=82)	Birch - 2.0% (n = 48)
	Lowland Conifer - 2.4% (n=82)	Lowland Conifer - 6.1% (n = 48)
	Cedar - 2.4% (n=82)	Cedar - 4.1% (n = 48)
	Lowland Hardwood - 1.3 (n=82)	Fir - 2.0% (n = 48)
		Grass - 2.0 (n = 48)
		Red Pine - 6.1% (n = 48)
Stocking Density/Size Class[2]	2 = 0% (n=82)	2 = 4.3% (n = 48)
	3 = 0% (n=82)	3 = 19.1% (n = 48)
	4 = 0% (n=82)	4 = 8.5% (n = 48)
	5 = 4.9% (n=82)	5 = 8.5% (n = 48)
	6 = 50% (n=82)	6 = 40.4% (n = 48)
	7 = 1.2% (n=82)	7 = 2.1% (n = 48)
	8 = 3.7% (n=82)	8 = 2.1% (n = 48)
	9 = 40.2% (n=82)	9 = 15.0% (n = 48)
Location of Nest (upland or lowland)	85% Upland (n=82)	85% Upland (n = 48)
	15% Lowland (n=82)	15% Lowland (n = 48)
Proximity to Upland Opening	181 m ± 46 (n=51)	231 m ± 184 m (n = 48)
Proximity to Wetland	362 m ± 97 m (n=51)	395 m ± 234 m (n = 48)

[1] The number of nests/random points, expressed as a percentage, occurring in a cover type.

[2] The number of nests/random points, expressed as a percentage, occurring in the following stocking density/size classes: 2 = medium stocked seedlings, 3 = well stocked seedlings, 4 = poorly stocked pole timber, 5 = medium stocked pole timber, 6 = well stocked pole timber, 7 = poorly stocked saw timber, 8 = medium stocked saw timber, and 9 = well stocked saw timber.

forested portions of the landscape. In contrast, random points had larger percentages of open-land habitat (Table 5). Nest sites were also surrounded by greater percentages of upland deciduous forest than random points (53% ± 6% upland deciduous forest cover for nest sites and 45 % ± 7% upland deciduous forest cover for random points). Further, random points had a greater portion of the landscape composed of upland conifer forest than nest sites (11% ± 4% and 7% ± 3%, respectively). The percent cover of wetland deciduous forest, lowland conifers, and open water was quite variable and occurred in small percentages for both nest sites and random points (Table 5). Nest sites tended to be located very near wetland habitat and upland openings (Table 5). In comparison, random points had highly variable distances to both wetlands and upland openings (Table 5).

The vast majority of nest sites (79.3%) were located in northern hardwood stands. Stands of aspen, oak, lowland conifer, and white pine contained smaller percentages of nest sites (Table 5). Random points were located in northern hardwoods at much lower percentages (Table 5). The vast majority of nests (90.2%) were also located in well-stocked pole/saw timber stands. Nests were never located in poorly stocked pole timber stands or seedling stands and occurred in small percentages in poorly and medium stocked saw log stands (Table 5). Nests and random points occurred in the exact same percentages for upland and lowland habitat (Table 5). Throughout the species' range, Red-shouldered Hawks are generally associated with floodplain forests (Evers 1994). However, Bednarz and Dinsmore (1981) found that Red-shouldered Hawks will use large, contiguous upland forest complexes, which may compensate for a lack of floodplain habitat. Postupalsky (1980) and Ebbers (1989) also documented Red-shouldered Hawks utilizing upland forest adjacent to wetland habitats in northern Michigan. In northern Michigan state forest areas, extensive tracts of mature floodplain forest are lacking. However, landscapes in these forest areas are composed of a complex matrix of upland forests and a variety of wetland habitats. Red-shouldered Hawks in the forest areas studied appear to select more heavily forested portions of the landscapes for nesting habitat that contain dense stands of deciduous/mixed forest. This is apparent when one compares nest sites to random points. Nest sites had higher percentages of forest cover and markedly higher percentages of upland deciduous forest cover. Random points had more open habitat and markedly higher percentage of upland conifer forest. Howell and Chapman (1997) and Johnsgard (1990) found that Red-shouldered Hawks nests tended to occur most frequently in forested landscapes composed of deciduous/mixed forest and tended to use coniferous forest sparingly. Results from this study concur with Howell and Chapman and Johnsgard's results. Nests also tended to be located in denser stands of timber (i.e., well stocked pole/saw timber) and were not found or occurred in smaller percentages in seedling stands and poorly to medium stocked pole/saw timber (Table 5). In contrast, random points occurred in all stocking classes, with the exception of classes 0 and 1 (Table 5). The percentage of nests occurring in well stocked saw timber, when compared to random points, was considerably higher (40.2% and 15.0%, respectively). These results give credence to the theory that Red-shouldered Hawks prefer relatively mature stands of deciduous/mixed forest for nesting habitat. Preston et al. 1989 and Jacobs and Jacobs (1997) describe Red-shouldered Hawks as using relatively mature stands of timber for nesting.

Red-shouldered Hawk nests also tended to be located very near wetland habitats (80 % within 463 m). The mean distance of nest sites to wetland habitat had a tight confidence interval (362 m ± 97 m), whereas the confidence interval for random points was quite variable (394 m ± 234 m) (Appendix III). What this data suggests is that Red-shouldered Hawks prefer portions

of the landscape near wetlands for nest placement. Random point distance to wetland habitat in the study area was quite variable. In a study in Georgia Howell and Chapman (1997) also found that Red-shouldered Hawks heavily exploit the ecotone between uplands and wetlands. The consistent documentation of nests near wetlands in our study follows habitat patterns noted by Howell and Chapman. Red-shouldered Hawk nests also tended to be located close to upland openings and the confidence interval for the mean distance to upland openings was fairly tight (Table 5 and Appendix III). In comparison, random points had a confidence interval for mean distance to upland opening that was quite large (Table 5 and Appendix III). What this suggests is that Red-shouldered Hawks prefer to place nests near small upland openings. Bosakowski and Smith (1997) found that Red-shouldered Hawks tended to place nests close to upland openings and wetlands as well.

Even though Red-shouldered Hawk nests tend to be relatively close to upland openings, it cannot be over emphasized that an increase in forest fragmentation (i.e., significant reduction in overall forest cover) across a landscape could likely result in an influx of nest competitors such as the red-tailed hawk (*Buteo jamaicensis*) and nest predators such as the great-horned owl. Both of these raptor species respond favorably to reduced forest cover (Bosakowski and Smith 1997), which could significantly inhibit Red-shouldered Hawk nesting success (Bryant 1986, Bosakowski and Smith 1997). Abatement of forest fragmentation can reduce the influx of nest predators and competitors. Currently, the red-tailed hawk population in the forest areas studied appears to be low, which is probably due to the heavy forest cover throughout the larger landscape. During the 1980's, Breeding Bird Atlas surveyors documented low to moderate numbers of red-tailed hawks in the current study area (Brewer et al. 1991). Furthermore, Ebbers (1989) also felt that red-tailed hawks were not a limiting factor in the forest areas surveyed. Great-horned owl abundance in the study area is likely low to moderate. Breeding Bird Atlas data from the 1980's indicates that great-horned owl numbers were low to moderate in the forest areas studied. However, in localized areas/sites this species may inhibit nest success of Red-shouldered Hawks. During 2000-2001 surveys, ten adult Red-shouldered Hawks were killed on or near the nest during the incubation or during the brood rearing stage. Based on evidence at the nest site (i.e., remains of a plucked bird), great-horned owls were most likely the predator. Moreover, Ebbers (1989) felt that in northern Michigan great-horned owls may be a factor that limits nest success in localized areas.

Nest Site Variables

The majority of nests were placed in mature beech trees (41%); only a few nests occurred in conifers (2%) (Table 6). Apfelbaum and Seelbach (1983) examined 283 Red-shouldered Hawk nests nation-wide and found that 90% of nest trees were deciduous and the most commonly used genera were oaks (*Quercus* spp.) and beech (*Fagus* spp.). Beech trees frequently provide optimal structure (i.e., multi-pronged crotch just below the canopy) and the presence of mature beech trees in hardwood stands may be a very important micro-habitat factor that influences hawk utilization of nesting habitat (Ebbers 1989). However, the diversity of nest trees utilized in Michigan seems to indicate that tree structure and not tree species is the most important factor that influences use of a tree for nest placement. Nests were typically placed high (14.1 m $\pm$ 0.37 m) and within a multi-pronged crotch of the tree, which concurs with results obtained by Titus and Mosher (1981). Nest trees also tended to be mature, tall, super-canopy trees (height =

25.26 m ± 0.56 m, dbh = 50.1 cm ± 1.8 cm). Nest percent (the nest height divided by the overall tree height multiplied by 100) was 56%. In a northern Michigan study conducted by Ebbers (1989) and a study in Maryland (Titus and Mosher 1981), nests were usually placed between 10.6 m – 18.3 m above the ground and 1/2 – 2/3 the way up the nest tree. Results from this study mirror rather closely the descriptions of nest tree structure in northern Michigan and Maryland.

Forty-four plots (0.04 ha) around nest sites and 35 plots (0.04 ha) around random points were sampled for structural attributes (Table 7). Stands of timber that housed Red-shouldered Hawk nests had higher canopies than random points. Basal area, tree density, canopy closure, and average dbh per plot were greater around nest sites than random points. Ground cover, sapling density and shrub density were highly variable for both nest sites and random points (Table 7).

Table 6. Nest tree species utilized by Red-shouldered Hawk at seven northern Michigan state forest areas (1998 – 2001).

Tree Species	Percent Used (n = 130)
American Beech (*Fagus grandifolia*)	41%
Maple (*Acer spp.*)	21%
Aspen (*Populus* spp.)	12%
White birch (*Betula papyrifera*)	10%
Basswood (*Tilia americana*)	6%
White ash (*Fraxinus americana*)	3%
Red Oak (*Quercus rubra*)	2%
Yellow birch (*Betula lutea*)	2%
American Elm (*Ulmus americana*)	1%
Jack Pine (*Pinus banksiana*)	1%
White pine (*Pinus strobus*)	1%

Table 7. Red-shouldered Hawk nest site characteristics at seven northern Michigan state forest areas (1998 – 2001).

Structural Attribute	Nest Site (n = 44)	Random Point (n = 35)
Nest Height	14.1 m ± 0.37 m	NA
	(46.2 ft ± 1.2 ft)	
Nest Tree Height	25.26 m ± 0.56 m	NA
	(82.9 ft ± 1.8 ft)	
Nest Percent	56.4% ± 1.5%	NA
Nest Tree dbh	50.1 cm ± 1.8 cm	NA
	(19.7 in ± 0.7 in)	
Canopy Height	16.12 m ± 0.48 m	11.89 ± 0.85 m
	(52.9 ft ± 1.6 ft)	(39.0 ft ± 2.8 ft)
Basal Area	11.1 m^2 ± 1.1 m^2	9.8 m^2 ± 0.8 m^2
	(123 ft^2 ± 12.7 ft^2)	(109 ft^2 ± 9 ft^2)
Tree Density/0.04 plot	19.1 ± 1.1	15.8 ± 1.5
Sapling Density	62.8 ± 9.5	58.2 ± 9.3
Shrub Density	84.0 ± 13.7	71.8 ± 12.9
Canopy Closure	88.3% ± 1.2%	74.7% ± 4.5%
Average Tree dbh/0.04 plot	10.7 ± 0.22	9.4 ± 0.73
Ground Cover	42.3% ± 4.2%	49.8% ± 5.2%

On average, stands of timber that housed Red-shouldered Hawk nests were taller and denser than random points and the 95% confidence interval for mean canopy height was rather narrow for nest sites and random points. This data may reflect Red-shouldered Hawks preferring taller stands of timber within forest complexes for nesting. Preston et al. (1989), Titus and Mosher (1981), and McLeod et al. (2000) also found that Red-shouldered Hawks prefer stands of timber with high canopies. Basal area around nest sites was high with little variation around the mean (Table 7, Appendix III). In contrast, random points had a fairly high basal area but greater variation around the mean was evident (Table 7, Appendix III). These results may suggest that Red-shouldered Hawks select stands of timber with higher basal areas and in un-occupied habitat basal area varies considerably. Kimmel and Fredrickson (1981), Portney and Dodge (1979), and Parker (1986) all found that Red-shouldered Hawks prefer stands of timber for nest placement that have high basal areas (99.5 ft^2 – 159 $ft.^2$). This study supports the results obtained by these researchers. Other nest site variables with tight confidence intervals that were greater than attributes at random points included tree density, canopy closure, and average dbh per plot. All of these variables suggest that Red-shouldered Hawks prefer the dense, relatively mature portions of forest complexes for nesting habitat. Further, these results are consistent with studies conducted by Ebbers (1989), Titus and Mosher (1981), and McLeod et al. (2000).

CONCLUSIONS

Hawk surveys on northern Michigan state forest areas were highly successful and great insight into nesting habitat utilization and distributional patterns within each forest area was gained. Further, all reproductive parameters (i.e., territorial re-occupancy, nest site fidelity, nest success) compare favorably with other studies concerning this species. However, lon-term data concerning productivity measures are needed to fully assess population viability. The Department of Natural Resources has developed draft management guidelines for Red-shouldered Hawks on state lands and are just beginning to implement them. The results from inventories and nest monitoring, at state forest areas studied, as well as future work in other Northern Lower and Upper Peninsula forest areas, should provide very valuable information. This information can be used to identify core areas of nest site concentration that support long-term viability, facilitate development of management guidelines, assess the impacts of forest management practices on habitat use and productivity, and evaluate the hawk's conservation status in Michigan.

FUTURE WORK

Over the next two years (contingent on funding) several woodland raptor nests will be monitored for territorial re-occupancy, nest site fidelity, nest success, and brood size. Habitat parameters (landscape and micro-habitat scales) will continue to be quantified and summarized for all nest locations documented to date. Ultimately, habitat data from multiple scales will be used to develop a predictive habitat model to facilitate management decisions. By the end of this multi-year project, we hope to compare attributes around successful nests and unsuccessful nests to better evaluate efforts to enhance reproductive success. We also hope to evaluate the effects of forest management activities on productivity, determine the appropriate state-listing status for woodland raptors in Michigan, and work cooperatively with the Wildlife Division and Forest, Mineral, and Fire Management Division to refine and finalize Management Guidelines for all woodland raptors.

ACKNOWLEDGEMENTS

This project was funded by the Michigan Department of Natural Resources, Forest, Minerals, and Fire Management (FMFM) (formerly the Forest Management Division (FMD), and the Wildlife's Natural Heritage Small Grants Program. FMFM staff contributed significantly to the project by helping delineate habitat for surveys, conducting surveys, helping organize volunteers, and providing valuable on-the-ground insight about the forest areas. The following FMFM staff have been an ongoing part of inventory efforts: Joe Jarecki, Rick McDonald, Kendal Phillips, Randy Heinze, Bill O'Neill, Steve Milford, Tim Paulus, Tim Greco, Don Stacks, Shannon Harig, Tom Stone, Greg Gatsey, Kim Lentz, Rich Barta, Don Middlestat, Scott Lint, Ernie Houghton, Bob Walters, Jim Bielecki, Cory Luoto, Amy Douglass, Matthew Edison, Jason Tokar, Karen Rodock, Brian Woodring, Tim Gallagher, and Steven Nyhoff. Brian Mastenbrook, Tim Webb, Sherry MacKinnon, and Doug Reeves (MDNR Wildlife) contributed significantly to the project by helping identify high quality habitat for surveys and providing valuable insight concerning the forest areas. Bill Moritz (MDNR Wildlife) gave helpful suggestions concerning study design and future data analysis. Other MDNR Wildlife staff that conducted surveys included Lorri Sargent (1998), Erin Victory (2000) and Kevin Gardiner (2001). Diane Hash (Conservation District Resource Professional) also helped with surveys in the TC Forest Management Unit.

Other Michigan Natural Features Inventory staff contributed to the project. Daria Hyde and Yu Man Lee conducted surveys in northern Michigan during 1998 and 1999. Peter Badra assisted with surveys during 1999, Jennifer Olson 1998, 99, 2001 and 2003, Michael Fashoway and Matt Smar 2001, and Josh Cohen, John Paskus, and Coburn Currier conducted surveys during 2000-2001. Rich Corner (former MNFI Ecologist) helped identify landscapes for surveys and provided useful insight about natural communities associated with the red-shouldered hawk. As always, MNFI administrative staff supported this project in countless ways. We are indebted to Sue Ridge, Laraine Reynolds, and Lyn Scrimger for the many tasks they complete that allows us to accomplish our work. Also, Judy Soule (former MNFI Director) supported this project and Mary Rabe (former Program Zoologists) helped conceive and design the initial study.

Numerous volunteers from the Pigeon River Forest Council assisted with surveys and their efforts are greatly appreciated, especially Judy Jarecki, Doug and Judy Mumert, and Mark Ennis. Jackie and Mark Schuler also assisted with surveys at the Indian River forest area during 1998. The assistance of Arch Reeves, former PRC Forest Technician, is greatly appreciated. Arch conducted extensive surveys at the PRC, provided a historical perspective about the red-shouldered hawk at the PRC, collected valuable productivity and life history data, and was the primary factor that surveys were so successful at the PRC.

Thanks to Seth Gallagher, graduate student at Central Michigan University, for his collection of data on the productivity and micro-habitat analysis from the Pigeon River Country State Forest during 2001-2002, and for his help during the 2003 field season. Bill Bowerman and Sergej Postupalsky provided useful insight concerning project design. Thank you is also extended to John Jacobs for his advice concerning nest productivity methodology and providing useful insight about red-shouldered hawk life history.

LITERATURE CITED

Apfelbaum, S.I., and P. Seelbach. 1983. Nest tree, habitat selection and productivity in seven North American raptors. J. Raptor Res. 17:99-104.

Armstrong, E., and D. Euler. 1982. Habitat usage of two woodland *Buteo* species in central Ontario. Can. Field-Nat. 97:200-207.

Barrows, W.B. 1912. Michigan bird life. Mich. Agric. Coll. Spec. Bull., E. Lansing.

Bibby, C. J., N. D. Burgess, and D.A. Hill. 1992. Bird census techniques. Academic Press, NY. 251 pp.

Bednarz, J.C. 1979. Productivity, nest sites, and habitat of red-shouldered and red-tailed hawks in Iowa. Master's thesis, Iowa State Univ., Ames.

Bednarz, J.C., and J.J. Dinsmore. 1981. Status, habitat use, and management of red-shouldered hawks in Iowa. J. Wild. Manage. 45:236-241.

Bosakowski, T. and T.G. Smith. 1997. Distribution and species richness of a forest raptor community in relation to urbanization. J. Raptor Res. 31(1):26 - 33.

Brewer, R.G., G.A. Mcpeek, and R. J. Adams, Jr. 1991. The atlas of breeding birds in Michigan. Mich. State Univ. Press, E. Lansing, MI. 594 pp.

Bryant, A.A. 1986. Influence of selective logging on red-shouldered hawks, *Buteo lineatus*, in Waterloo region, Ontario, 1953-1978. Can. Field-Nat. 100:520-525.

Cooper, J.L., D.L. Cuthrell, M.L. Rabe. 1999. Red-shouldered hawk inventories and assessment of nest productivity at the Pigeon River and Indian River Forest Areas. Report submitted to Michigan Department of Natural Resources, Forest Management Division, Lansing.

Cooper, J.L. and D.L. Cuthrell. 2000. Red-shouldered hawk productivity, landscape analysis, and nest site selection on state forest lands in Northern Michigan: Year 2000 report. Report submitted to Michigan Department of Natural Resources, Forest Management Division, Lansing, MI. 45 pp.

Craighead, J.J., and F.C. Craighead. 1969. Hawks, owls and wildlife. Dover Publishing, New York, N.Y.

Dijak, W.D., B. Tannenbaum, and M.A. Parker. 1990. Nest-site characteristics affecting success and reuse of red-shouldered hawk nests. Wilson Bull. 102:480-486.

Ebbers, B.C. 1986. Distribution, status, and reproductive ecology of red-shouldered hawks in the northern lower peninsula of Michigan. Report submitted to Michigan Department of Natural Resources, Lansing.

Ebbers, B.C. 1989. Relationship between red-shouldered hawk reproduction and the environment. Report submitted to

Michigan Department of Natural Resources, Lansing.

Evers, D.C. 1994. Endangered and threatened wildlife of Michigan. Univ. Michigan Press, Ann Arbor. 411 pp.

Henny, C.J., F.C. Schmid, E.M. Martin, and L.L. Hood. 1973. Territorial behavior, pesticides, and population ecology of red-shouldered hawks in central Maryland, 1943-71. Ecology 54:545-554.

Howell, D.L., B.R. Chapman. 1997. Home range and habitat use of red-shouldered hawks in Georgia. Wilson Bull. 109:131-144.

Jacobs, J.P. and E.A. Jacobs. 1997. Summary of red-shouldered hawk reproduction in northeastern and central Wisconsin. Unpublished report submitted to the Wisconsin Department of Natural Resources, Bureau of Endangered Resources, Madison. 11pp.

Jacobs, J.P. and E.A. Jacobs. 1998. Summary of red-shouldered hawk reproduction in northeastern and central Wisconsin. Unpublished report submitted to the Wisconsin Department of Natural Resources, Bureau of Endangered Resources, Madison. 11pp.

Jacobs, J.P. and E.A. Jacobs. 2000. Summary of red-shouldered hawk reporduction in northeastern and central Wisconsin. Unpublished report submitted to the Wisconsin Department of Natural Resources, Bureau of Endangered Resources, Madison. 9 pp.

Jacobs, J.P., E.A. Jacobs, and T.C. Erdman. 1988. Nesting ecology of the red-shouldered hawk. Proc. Annual Meeting, Raptor Res. Found., Oct. 27-29, Minneapolis.

Janik, C.A. and J.A. Mosher. 1982. Breeding biology of raptors in the central Appalachians. J. Raptor Res. 16:18-24.

Johnsgard, P.A. 1990. Hawks, eagles and falcons of North America. Smithsonian Institution, Washington, D.C. 402 pp.

Kennedy, P.L., and D.W. Stahlecker. 1993. Responsiveness of nesting Northern Goshawks to taped broadcasts of three conspecific calls. J. Wildl. Manage. 57:248-257.

Kimmel, V.L., and L.H. Fredrickson. 1981. Nesting ecology of the red-shouldered hawk in southeatern Missouri. Trans. Missouri Acad. Sci. 15:21-27.

Kochert, M.N. 1986. Raptors *in* Inventory and monitoring of wildlife habitat. Cooperrider, A.Y.,R. J. Boyd, and H. R. Stuart. (eds). U.S. Dept. Inter., Bur. Land Manage. Service Center. Denver, Co. 858 pp.

McLeod, M.A., B.A. Belleman, D.E. Anderson, and G.W. Oehert. 2000. Red-shouldered hawk (*Buteo lineatus*) in southestern Minnesota. Wilson Bull. 112(2): 203 – 213.

Natural Heritage Biological and Conservation Data System. 2001. Consolidated by Michigan Natural Features Inventory, Lansing, MI.

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, South Dakota. 399 pp.

Parker, M.A. 1986. The foraging behavior and habitat use of breeding red-shouldered hawks (*Buteo lineatus*) in southeastern Missouri. M.A. thesis, Univ. MO, Columbia. 90 pp.

Portney, J. W. and W.E. Dodge. 1979. Red-shouldered hawk nesting ecology and behavior. Wilson Bull. 91:104 – 117.

Preston, C.R., C.S. Harger, and H.E. Harger. 1989. Habitat use and nest-site selection by red-shouldered hawks in Arkansas. The Southwestern Nat. 34(1): 72 –78.

Postupalsky, S. 1980. The red-shouldered hawk breeding in Michigan's Upper Peninsula. Jack Pine Warbler 58:73-76.

Stavers, J.W., K.J. McKay, E. Nelson. 1995. Red-shouldered hawk reproductive success within pools 9-11 of the Upper Mississippi River, 1983-94. J. Raptor Res. 29:67.

Stewart, R.E. 1949. Ecology of a nesting red-shouldered hawk population. Wilson Bull. 61:26-35.

Titus, K., and J.A. Mosher. 1981. Nest-site habitat selected by woodland hawks in the Central Appalachians. Auk 98:270-281.

Trexel, D.R., R.N. Rosenfield, J.Bielefeldt, E.A. Jacobs. 1999. Comparative nest site habitats in sharp-shinned and Cooper's hawks in Wisconsin. Wilson Bull. 111:7-14.

Wiley, J.W. 1975. The nesting and reproductive success of red-tailed and red-shouldered hawks in Orange County, California, 1973. Condor 77:133-139.

Woodfry, M.S. 1986. Characteristics of red-shouldered hawk nests in southeastern Ohio. Wilson Bull. 98:270-281.

APPENDIX I

Forest Compartments and stands surveyed for red-shouldered hawks at nine northern Michigan state forest areas (1998-2003).

The following table shows compartments and stands surveyed and habitat types targeted for surveys at the seven state forest areas 1998-2001.

Compartment	Stands Surveyed	Habitat(s) Surveyed [1]
PRC-4	Special Management Unit	M9
PRC-6	10	A6
PRC-7	18, 43, 53, 59, 60, 61, 8, 56	A6, M6, M9, W6, A5
PRC-8	12	M9
PRC-9	5, 4, 1 15, 10, 22, 21, 20, 33, 31, 33, 39, 62, 46, 59, 51, 44	A6, E6, M6, M9, Q6
PRC-10	10, 5, 18, 21, 35, 34, 40, 44, 55, 58, 65, 25, 26	M6, A6, A2
PRC-11	52, 53, 50, 58, 22	M9, E6, A6, A9,A3
PRC-12	17, 22, 33, 51, 84	A6, M6, E6, A3
PRC-13	12, 2, 7, 6, 5, 18, 53	M6, M9,A3
PRC-14	1, 4, 31, 35, 37, 50, 47, 55, 59, 60	M9, M6, A5, E9
PRC-15	26, 60, 62, 46, 66, 75, 76, 73, 72, 71, 78, 77, 80, 53	E5, M6, M8, A6, P5, Q6, W6, E6,A3
PRC-16	52, 47, 44, 16, 40	M6, M8, M5, W8
PRC-17	13, 21, 23, 100, 62	M6, M9, M5, G, R9
PRC-18	45	M6/9
PRC-20	69, 41, 5, 8	M6, A6, C6, A0
PRC-21	58, 38, 14, 4, 58	A5, M6, E5, E6, R9
PRC-22	1, 17, 26, 7	M6/9
PRC-23	48, 67	A5, A6, M6, E5, O6, A3, F2
PRC-24	38, 40, 41, 34, 92, 85, 33, 47, 24, 21, 53, 56, 49, 50, 94	M6, E5, A5, B6, A4
PRC-26	13, 8, 25, 28	O9, M6
PRC-29	16, 12, 14	E6, M6
PRC-30	119, 30, 10, 8	M6/9
PRC-33	72, 74, 46, 36, 31, 29, 44, 27, 32, 18, 28, 21, 18, 9	A5, M6, M9, A3
PRC-35	21, 33, 20, 16, 29	M6, O9, M9, R6
PRC-37	9, 6, 7, 12, 14, 15, 51	M6, M8, M9, O8, M5, W8
PRC-39	21, 22, 56, 27, 28, 59, 38, 39, 2, 1	M6, O5, M9, B6, Q5
PRC-40	39	O7, A2, R8, W5/7
PRC-41	1, 39, 56, 62, 71, 9	A6, O6, M6, C6, W9, O7, T4
PRC-42	62, 57, 53, 38, 37, 35, 11, 30, 9, 6	A5, M5, M6, O5, R7, J5
PRC-43	24, 25	M8, W8, A2
PRC-45		
PRC-46	36, 130	M6, Q6, W8, L
PRC-47	7, 4, 2, 17, 13, 15, 17, 22, 27, 23, 26, 28, 29, 30, 32, 39, 50, 56, 62, 64, 56, 57	O6, M6, M9, B6, O9, W9
PRC-48	14, 5, 1, 9, 19, 23, 34, 37, 35, 48, 44, 56, 37	A6, M6, O6, A1, Q4
PRC-49	21, 15, 6, 55	A5, J3
PRC-52	56, 41, 56	O6, M5, C4
PRC-53	60, 81, 56, 42, 39, 38, 37, 14, 11, 4	M5, M6, E5, A5, A6, M9,C6
PRC-54	1, 2, 19, 22, 7, 6, 5, 21, 25	M5, M8
PRC-55	6	M6
PRC-56	11, 10, 15, 16, 19, 22	A6, O6
PRC-57	30, 29, 26	M6
IR4	46, 40, 45, 47, 48, 21, 22, 23, 24, 26, 27, 13, 12, 11, 20, 14, 32, 54, 6, 7,	A6/9, M6/9
IR6	9, 24, 20	A5/66
IR15	19, 14, 5, 6, 13, 19, 29, 36, 44, 43, 33, 47, 46	M6/9, A6

Compartment	Stands Surveyed	Habitat(s) Surveyed [1]
IR16	2, 3, 5, 15, 9, 17, 10, 23, 44, 49, 41, 45, 11, 52, 55, 42, 39, 51	M6/9, A6
IR21	1, 22, 19, 23, 24, 26, 28, 30	M6/9, A5, A9, A3, W8, C6
IR22	3, 7, 11, 21, 19, 12, 15, 28, 7, 26	M6/9, W8, A3
IR30	17, 18, 21	E6, E8, B6
IR36	1, 3, 4, 13, 44, 47, 39, 23, 36, 28,	O6, A6, R6
IR39	4, 5, 2, 1	E6, M9, A9, A3
IR50	11	M9
IR57	117, 317, 417, 310,	M6
IR58	34, 37, 30, 29, 28, 27, 33, 35, 10, 4, 2, 3, 25, 21, 17, 44, 48, 46, 54, 55, 63, 60, 66, 59,l 67, 68	M6/9, P5, A6
IR59	6, 10, 1, 3, 13, 36, 37, 41, 38,	M6/9, E5
IR76	40, 7, 14, 39, 22, 39, 40,	A6/9, Q6, B6, P6
IR78	1, 11, 30,	A6/9, M6/9
IR82	2, 6, 9, 19	M6/9,
IR83	90, 84, 103, 86, 100	B6, M6, A5
IR88	3	M6
IR89	15, 8, 35, 235, 244, 38, 37, 28, 2, 1, 236, 36, 39, 139, 136,	M6/9, A6/9, B6, A3, G, C6, L
IR100	19 (Atlanta 174)	B6
IR106	18, 118, 1	E9, P6, A6, A3, J5
IR109	9, 12, 15, 18,19,	E9, A6/9, A4, R6
IR110	14	A6
IR111	33, 36, 31, 28, 29, 28,	A6, M6
IR153	60	A6
GA 34	47, 27,23, 18, 13	M6, A3, M9, G
GA 44	67, 73, 66, 24	A9, M9, M6, Q6
GA54	18, 15, 37	M6, Q6
GA 39	113, 222, 112, 111, 115, 114, 221, 110, 109, 223, 220, 107, 72, 119, 73, 47, 22, 1, 2, 5, 7, 24, 182	M6, E6, A6, E3, G, M9, A3
GA 40	23, 2, 9, 13, 50, 54, 56, 54, 72, 60	Q6, R9, M6, M8, M5, N
GA 41	30, 50, 24, 49, 26, 43, 21, 44, 52	A3, M6, G, O9, M9, M5
GA 50	8, 7, 10, 12, 20, 21, 22, 23, 34, 24, 37, 28, 26, 27	M9, M6, F6, M6, G, M5
GA 55	51, 42, 11, 43, 44, 18, 45, 4, 2, 35	G, M5, M7, M6, A3
GA 51	56, 50, 59, 51, 52, 49, 48	C3, A6, Q6, L, G, A3
GA 37	61, 63, 18, 67	C7, M8, M6, M7, Q9
GA 43	22, 19, 24, 27	M9, A3
GA 57	3, 7, 31, 36, 5, 11, 19, 15, 15, 35	Q6, A5, M6, G, A6, A5
GA 49	2, 39, 40, 3, 43, 7, 51, 4, 31, 33, 17	M6, M9, R2, U, A6
GA 48	10, 11, 6, 8, 24, 25, 32, 43, 44, 45, 46, 34, 26	M8, M6, M7, Q6, N, M4, G, A3
GA 47	1, 37, 2, 31, 41, 40, 13, 44, 14, 16, 23, 22, 18, 47, 33, 46, 27, 28	M5, M6, M7, M8, G, Q6, N, A3, C4, M4, L
GA 36	1, 52, 12, 54, 53, 17, 16, 15, 55, 3, 28, 27, 45, 46, 5, 3, 1, 61, 62,	A3, A6, G, R9, R6, A3, M5, M7, M9, M8
TC 34	4, 6, 8, 9, 100, 24, 29, 54, 42, 3, 83, 105, 60, 68, 41, 42, 43, 74, 33, 63, 75, 80	R6, A6, A3, M6, M9, M5, A3, G, E6, E9, E1
TC4	111, 40, 33, 44, 46, 85, 95, 91, 82, 94, 99, 101, 72, 70, 69, 64, 68, 63, 72, 98, 101, 90, 110, 107, 25, 19, 7, 103, 78	L, M9, M4, G, M6, A6, W7, M5, A4, M8, M5, M4, M8, W6, R6
TC 7	17, 10, 52, 16, 15, 53	M9, M6
TC 16	63, 113, 54, 57	M8, M9, M7, M6, A3
TC 49	86, 85, 95, 96, 93, 100, 8, 4, 30, 28, 66, 61, 51, 19	A3, C6, A4, E9, E6, M6, R6

Compartment	Stands Surveyed	Habitat(s) Surveyed [1]
TC39	23, 49, 22, 83, 3, 19, 20, 75	L, E6, G, W9, E7, E5, P3
TC9	3, 35, 36, 37, 39, 41, 3, 2, 11, 12, 15, 5, 21, 20, 22, 19, 25	M6, G, M9, A6, R6
TC36	115, 26, 25, 23, 18	E1, M9, Q6, W6, A6
TC35	34, 41	M6, W6
GL-5	100, 101, 116, 103, 120, 123, 122	A6, E8, E9, E2, A9, P6, O9
GL-10	53, 94, 95	W7E6, E9, Q6
GL-12	25, 27, 22	O9, A6
GL-48	3, 11, 17, 26, 32	E6, E9, A6
GL-63	3, 4, 5, 39	E9, E6, A3
GL-75	17, 21, 28, 67, 79	A6, A9, O6, E6
GL-83	1, 5, 8, 16, 19, 20, 23, 27	M6, E6, A6, E9
GL-96	Not numbered	A6
GL-99	16, 22, 37, 38, 41, 48, 49, 52	A6, E6, O6, M6
GL-105	1, 11, 5, 101	E9, E5
GL-113	38	O9
GL-115	65, 64	E9, A6
GL-124	8, 9	E8E6, O7
GL-125	42	E6
GL-127	9, 28, 26, 31	E6, A6
NAU-148	58, 59	M6, M9
NAU-168	33, 51	Q5, M6
NAU-197	75	M6
NAU-180	2, 3, 4, 10, 13, 18, 16	M9, M6, H9
NAU-137	34, 35	R9
NAU-167	Stalking crane hardwoods	M6
NAU-169	Stalking crane hardwoods	M6
NAU-172	26, 28, 29	M6, M9
NAU-105	22	C6
NAU-156	44, 47, 91	M9, M6
NAU-157	44, 43, 64, 68, 67	B6, M9, M6
NAU-198	2, 3, 5, 12, 28	M9, M6
NEW-79	38, 39	M6, M4
NEW-100	59, 60	M6
NEW-107	1, 7, 16, 19, 32	M6, E9
NEW-119	3, 4, 6, 15	M6, A6
ATL-15	11, 13, 57, 63	M6, B6, M9
ATL-16	18, 22, 25, 27, 34, 35, 36, 37, 39, 42	M6
ATL-29	14	M9
ATL-44	4, 5, 6	B6, M9
ATL-72	1, 9, 13, 27, 38, 41, 32	M6, M9
ATL-85	8, 12, 16,	E5, E6, R7
ATL-105	62, 63, 66, 70	E7E5, E6, R6
ATL-173	3, 20	M6, P6
ESC-1	1, 14, 15, 67, 77, 78, 114, 133	M6, M9, A6, E6
ESC-2	11, 15, 16, 22, 23, 26,	M6, A6
ESC-3	11, 14, 15, 18, 33, 40, 46	M6
ESC-52	1, 2, 3, 28, 46	M6, E6
ESC-57	1, 2, 4, 9, 22	M6, E9
ESC-60	16, 17, 19	M4, M6
ESC-83	14	M6
ESC-91	63, 85	M6
ESC-112	51, 62	M5, M9

[1] Habitat types follow Michigan Department of Natural Resources Forest Operational Inventory (OI) designations and are defined as follows: M = northern hardwoods, E = lowland hardwoods, B = birch, A = aspen, W = white pine, P = balsam poplar, R = red pine, C = Cedar, F = spruce-fir J = jack pine, L = lowland brush, G = grass, O = oak, and Q = lowland conifers. Corresponding numerical values follow OI stocking density/size classes and are defined as follows: 0 = non-stocked, 1 = poorly stocked seedling/sapling, 2 = medium stocked seedling/sapling, 3 = well stocked seedling/sapling, 4 = poorly stocked pole timber, 5 = medium stocked pole timber, 6 = well stocked pole timber, 7 = poorly stocked saw timber, 8 = medium stocked saw timber, and 9 = well stocked saw timber.

APPENDIX II

MNFI Raptor Nest Reporting Form

RAPTOR NEST REPORTING FORM

Michigan Natural Features Inventory

Site Information
Observer(s) Name:_____ **Phone**:_____ **email**:_____
County:_____ **State Forest Area**:_____ **Compartment/stand**:_____
Date of Observation:_____ **Township/Range/Section:**_____
Directions to Site:_____
Survey and Biological Data
Weather (check): sunny ☐ mostly sunny ☐ partly cloudy ☐ mostly cloudy ☐ cloudy ☐
winds: 0-5 ☐ 6-10 ☐ 11-15 ☐ 16-20 ☐ 20+ ☐ **Temperature:** ____
Precipitation: rain ☐ snow ☐
Circumstance of Observation:deliberate search ☐accidental observation ☐ responded to taped call ☐
Raptor Species Observed: red-shouldered hawk red-tailed hawk broadwing hawk northern goshawk Cooper's hawk northern harrier bald eagle osprey peregrine falcon merlin kestrel short-eared owl long-eared owl great horned owl other_____
Rank your identification: extremely confident confident some reservation not sure no clue
Describe individuals observed: # of adults_____# of juveniles_____
(check all that apply) birds heard calling ☐ birds observed but not calling ☐ birds observed & heard ☐
Nest Found (check all that apply): no☐ yes ☐; if yes nest decorated ☐ not decorated ☐ old nest ☐
presence of down ☐ evidence of new construction ☐ bird on nest ☐ birds heard in immediate vicinity of nest ☐
Nest tree species:_____ **Nest height:** 10-20' ☐ 21-30' ☐ 31-40' ☐ 41-50' ☐ 50'+ ☐
Nest tree DBH :_____**Age class**: Even ☐ Uneven ☐ **Presence of flight lane**: yes ☐ no ☐
Landscape Position: Slope ☐ Flat ☐ Upland ☐ Lowland ☐ **Canopy layers**: 1 ☐ 2 ☐ 3 ☐
Proximity to wetland (mi.): < 1/8 ☐ >1/8<1/4 ☐ >1/4<1/2 ☐ >1/2 ☐
Type of wetland habitat nearby: Conifer ☐ Hardwood ☐ Emergent ☐ Vernal Pool ☐ Shrub ☐
Other: _____

Understory density: Dense ☐ Moderate ☐ Sparse ☐ **Cover type**: M☐ A☐ B☐ O☐
Other_____
Stocking density: 5☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐

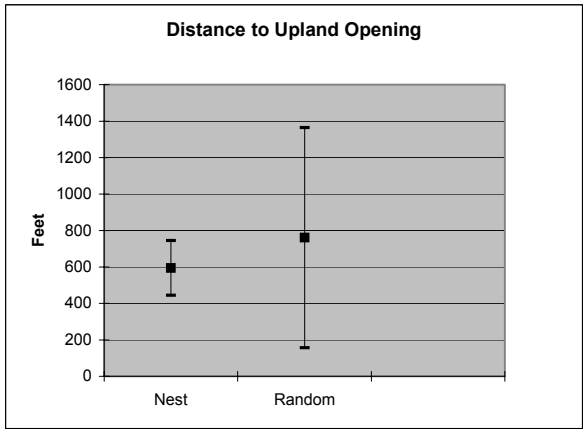
Productivity Surveys (if conducted)
Date:_____ **Observer(s):**_____ **Active**: Yes ☐, if yes young in nest ☐ whitewash at base of tree ☐ young of year in nearby trees ☐ No ☐ **Number of Young**: _____
Was there evidence of predation: no ☐ yes ☐If yes, nest torn apart ☐ claw marks on tree ☐ dead bird in or near nest ☐ other_____
Additional notes: _____
_____

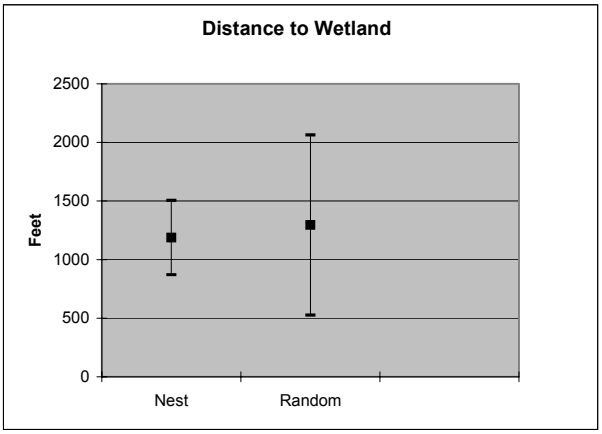
Please draw a map of nest site on back of form or attach compartment map or topographic map
Send completed form to:
Dave Cuthrell, Michigan Natural Features Inventory, P.O. Box 30444, Lansing, Michigan 48909
For additional information: Dave Cuthrell, zoologist (517) 335-6627 Email: cuthreld@state.mi.us

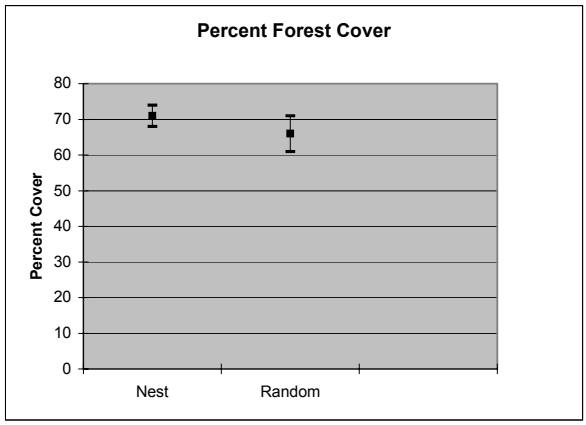
APPENDIX III

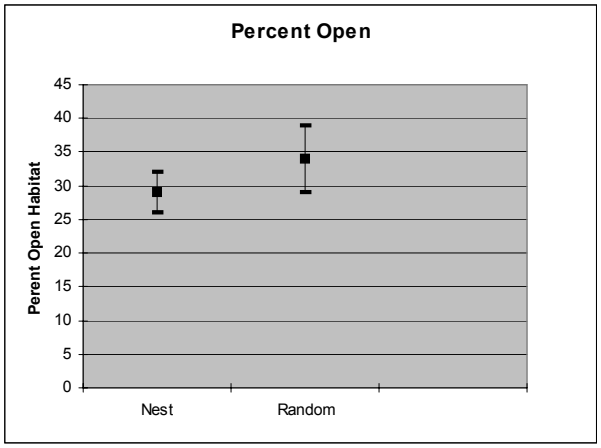
Means and Confidence Intervals (95%) for Landscape and Micro-habitat Variables for nest sites and random points

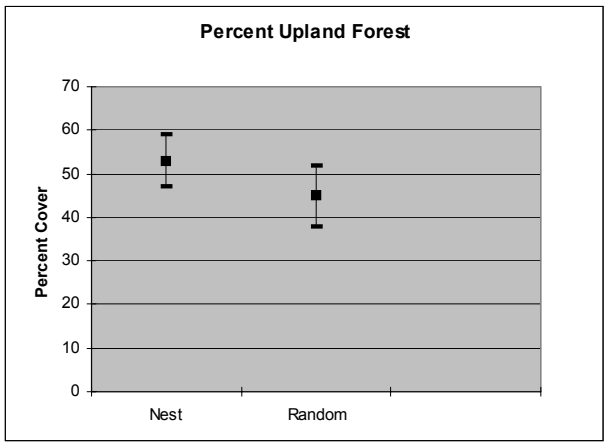
Landscape Attributes (n = 51 for nest sites and n = 48 for random points)

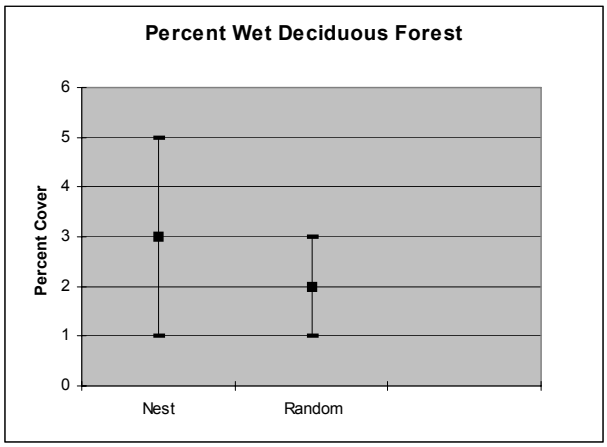


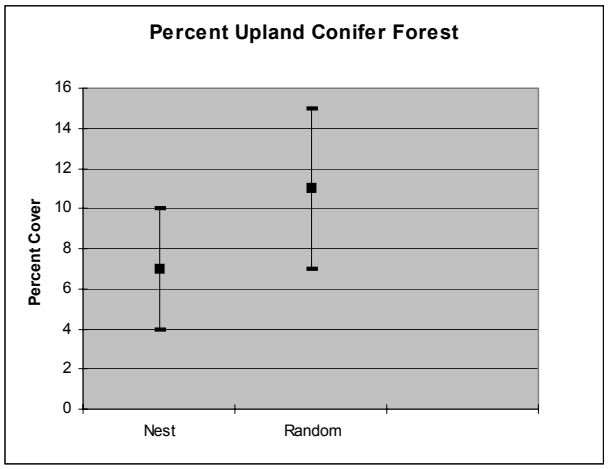


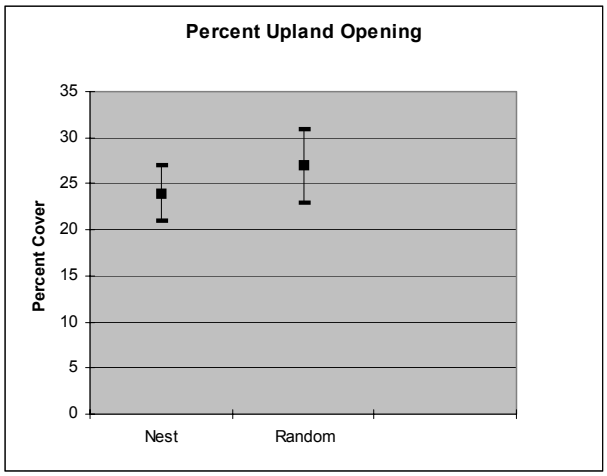


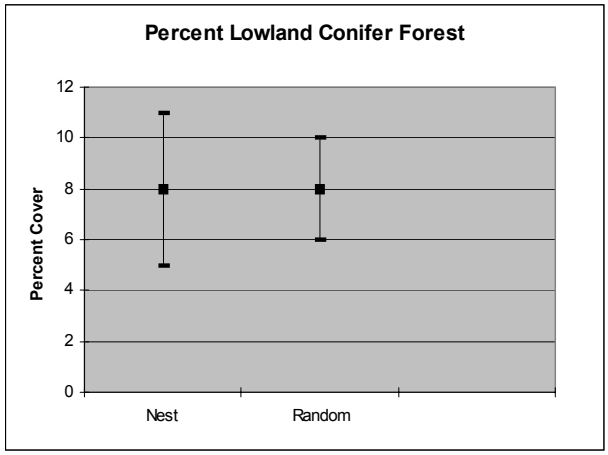


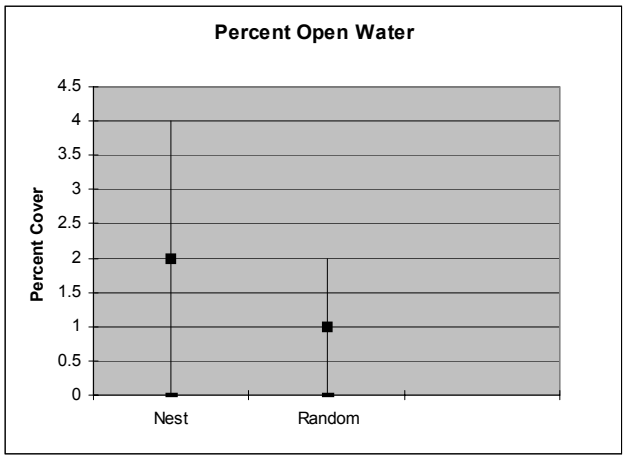


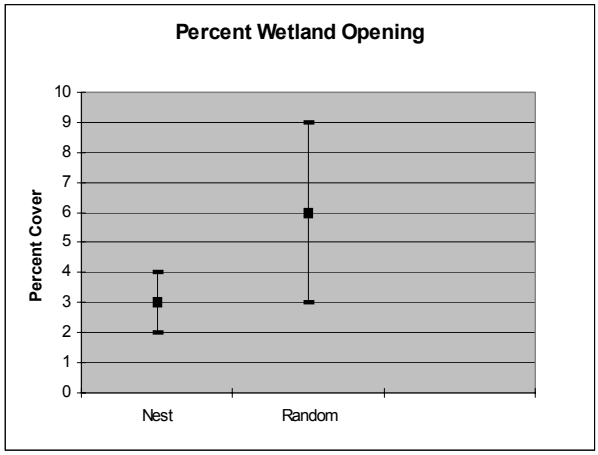



Percent Upland Conifer Forest
Percent Cover
16
14
12
10
8
6
4
2
0
Nest
Random

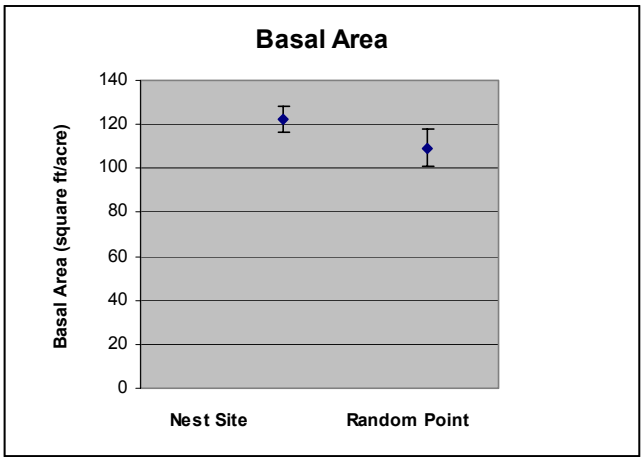

Percent Upland Opening
Percent Cover
35
30
25
20
15
10
5
0
Nest
Random

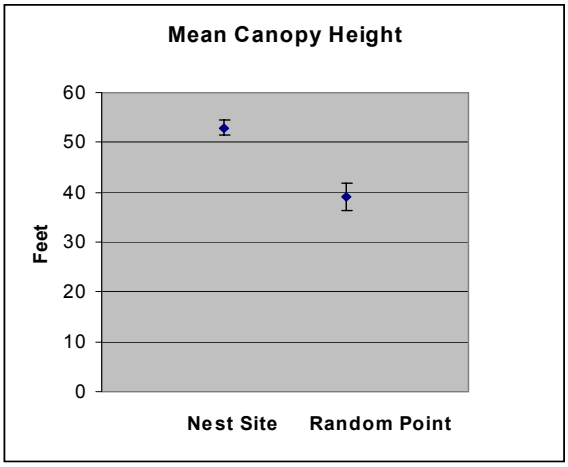

Percent Lowland Conifer Forest
Percent Cover
12
10
8
6
4
2
0
Nest
Random

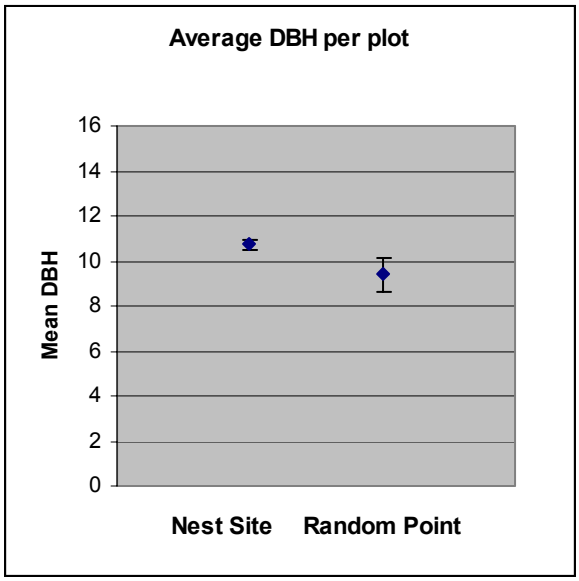

Percent Open Water
Percent Cover
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Nest
Random

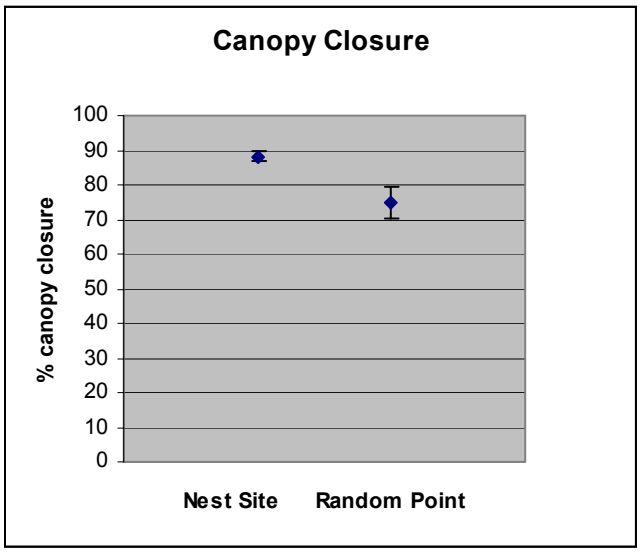

Percent Wetland Opening
Percent Cover
10
9
8
7
6
5
4
3
2
1
0
Nest
Random

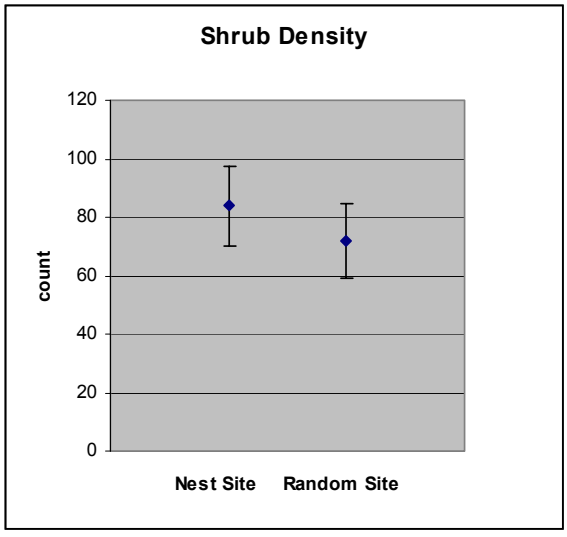
Micro-habitat Attributes (n=44 for nest sites and n=35 for random points)

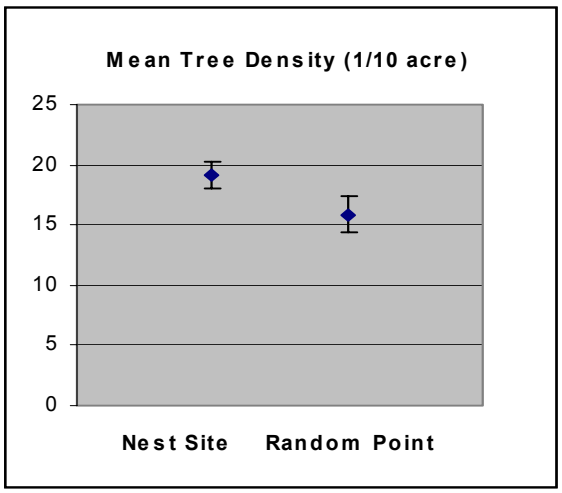


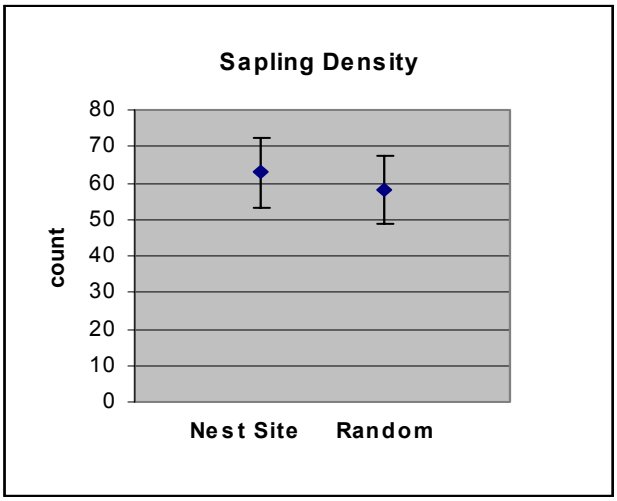


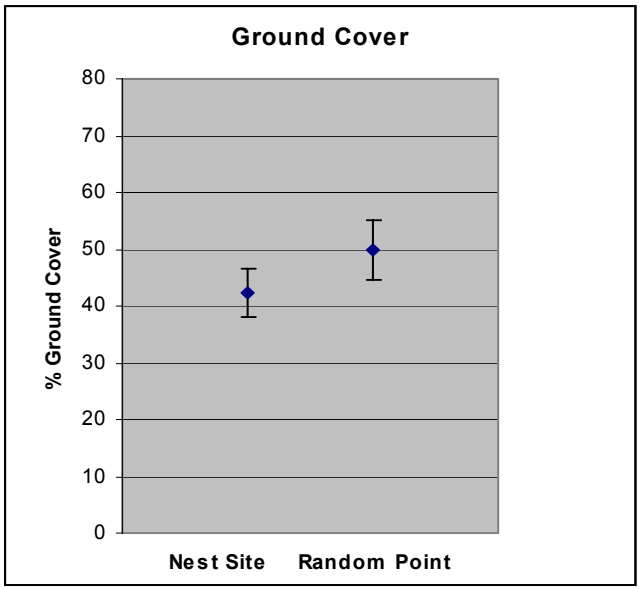









Sapling Density
count
80
70
60
50
40
30
20
10
0
Nest Site
Random


Ground Cover
% Ground Cover
80
70
60
50
40
30
20
10
0
Nest Site
Random Point

ABOUT THE AUTHOR

David L. Cuthrell received a M.S. Degree in Entomology from North Dakota State University and a B.A. Degree in Biology from the University of Northern Iowa. Currently David is a zoologist with the Michigan Natural Features Inventory, Michigan State University Extension, a position he has held since 1994. David has been surveying and studying woodland raptors since 1995. He is responsible for planning and conducting inventories for rare invertebrate and vertebrate animals, processing rare animal data, and environmental review assessments. Some recent projects David has been involved with include a study of wetland nesting birds in southeast Michigan, a survey for insects associated with lakeplain prairie remnants, and developing woodland raptor training sessions. His other research interests include prairie and barrens associated insects, pollinators of rare plants, grassland/wetland birds, and of course raptors.

Phone: 517-335-6627 *email: cuthreld@state.mi.us*

Cover Photo Identification and Credits:
All photos by author

Left: Using mirror pole to count young Red-shouldered Hawks, Traverse City Forest Area, June 2002.

Top Right: Three young birds on nest, Indian River Forest Area, June 2003.