WOODLAND HAWK CENSUS PROJECT

Final Report - 1987

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TABLE OF CONTENTS

INTRODUCTION

It is essential to the effective management and conservation of wildlife populations to be able to reliably assess their status over space and time. Such quantitative data for woodland raptors have been difficult and often prohibitively expensive to acquire. Public and private concern for these species has led to requirements for determining their status within political boundaries by both State and Federal agencies.

Forested habitat places severe restrictions on our ability to detect and observe raptors. Detectability is further reduced by the secretive behavior of several of these species. This project, final results of which are reported here, was initiated in 1979 to develop methods for monitoring raptor populations in forested habitat. We asked these questions among others: 1) do woodland raptors respond to broadcast of tape-recorded conspecific and/or Great-horned Owl vocalizations? they do; 2) does the use of these broadcast vocalizations increase the detectability of raptor species over surveys without broadcast? it does; 3) which is most effective at eliciting responses from woodland hawks, conspecific or Great-horned Owl broadcasts? of the species tested, the Great-horned Owl broadcasts produced higher contact rates for Red-shouldered Hawks and rates at least as high as the conspecific broadcasts for other species; 4) is

there a correlation between survey contact rates and the actual number of hawks resident on the area surveyed? yes.

This report presents the results of the final development and testing of the broadcast technique for censusing/indexing woodland hawk populations. The best regression models for individual species and species groups are presented along with their statistical characteristics. Recommendations for the application of this technique to monitoring woodland hawk populations are provided.

FIELD PERSONNEL AND ACKNOWLEDGMENTS

Field data were collected by the following individuals: O. Anderson, J. Brundage, J. Coleman, G. Cress, J. DiDonato, C. Dorff, N. Douglass, C. Grupenhof, D. Hazlett, A. Hershner, R. Hollister, V. Jones, B. Kenney, C. Kilpatrick, L. Nyland, J. Pope, W. Roberts, M. Shields, K. Titus, and G. Willey. The cooperation and assistance provided by personnel of the Maryland Department of Forest Parks and Wildlife, Savage River State Forest, Green Ridge State Forest, Indian Springs Wildlife Management Area, Pokemoke State Forest, Ohio Department of Natural Resources, Zaleski State Forest, Minnesota Department of Natural Resources, St. Croix State Forest and State Park (MN), Smokey Hills State Forest (MN), Whitewater Wildlife Management Area (MN) and the Superior National Forest (MN) are gratefully acknowledged. The following individuals merit special recognition for their support of this project during its various stages: J. Ruos, M. Fuller, G. Taylor, D. Case and especially L. Pfannmuller. P. Geissler generously provided statistical assistance.

METHODS

Census Routes

Point transects of unlimited width were established along roads on study areas in Maryland, Ohio, and Minnesota. One raptor species was designated as the target species whose recorded vocalization would be broadcast for each study area along with the broadcast of Great-horned Owl vocalizations on paired road counts. Transects were 7.2km (4.5mi) long, consisting of ten stations at 0.8km (0.5mi) intervals. Each study area extended to a radius of 1.6km (1.0mi) beyond the first and last stations and 1.6km (1.0mi) to each side of the transect encompassing about 31.1km (12m2).

Point transect counts were conducted at approximately 7 to 10 day intervals throughout breeding season. A count is defined as the process of enumerating contacts with raptors at the 10 stops along each transect. Counts began shortly after sunrise.

The weather conditions under which counts were conducted were those specified for the Breeding Bird Survey (Robbins and Van Velzen 1967). Essentially, counts were not made in fog, steady drizzle, prolonged rain, or winds greater than Beaufort 3 (13 - 19km/hr).

Observers remained at each stop for 10 minutes. Data were recorded in two periods: a 5-minute broadcasting period; and a 5-minute period following the final broadcast vocalization.

The starting and ending times were recorded at each stop. The following information was recorded for each raptor contact:

1. Species.
2. Contact type: whether bird was seen and/or heard.
3. Latency: the length of time, in minutes, from the first broadcast vocalization until the contact.
4. The compass bearing and approximate distance from the stop to each contact.

A contact was defined as any observation of a raptor either visual or auditory. Separate contacts recorded along transects are not assumed to be necessarily of different individual birds. However, observers were instructed to use the proximity in space and time as well as vocal characteristics of contacts to minimize recounting of the same individual at the same stop. No attempt was made to avoid counting the same individual at adjacent or subsequent stops.

The 5-minute broadcasting period consisted of six 15- second vocalizations evenly distributed over 5 minutes. The speaker, placed about 2.0m above the ground was rotated 180o after each set of vocalizations, resulting in 3 sets of calls being broadcast toward each side of the transect at each stop. The speaker was either horizontal or inclined upwards parallel to an ascending slope. Raptor vocalizations used in this study were recorded onto 6-min continuous loop cassette tapes from commercially available bird song and call record albums (Peterson Field Guide Series, A Field Guide to Bird Songs of Eastern and

Central North America or National Geographic Society, Bird Sounds of Marsh, Upland and Shore). Portable public address broadcast equipment of several types was used. For each set of equipment, output was adjusted between 100 and 110 decibels using a Realistic, battery operated sound level meter set to weighting scale C and slow response.

Nest Searches

Study areas were systematically searched on foot for raptor nests during the breeding season over a period of 12 to 14 weeks, generally between early April and the first week of July. All observations of raptors were recorded in field notes and plotted on topographic maps. For each observation, the species, age (if known), date, and behavior were recorded. Separate maps were kept for census route contacts and all other field contacts. The maps of field contacts were used to decide if any pairs of hawks, which were not accounted for by the active nests found, were resident on the study areas. When there was doubt about whether a group of observations, e.g. 2 or 3 sightings of an adult Broad-winged Hawk in the same vicinity, were associated with a known active nest I choose to not count them as a separate pair. This was a subjective process. However, to be counted as a resident pair, 1) 2 or more contacts with the same species must have been recorded in the same area and, 2) that area must have been at least 1.5mi from the nearest known nest of that species in the case of Broad-winged, Sharp-shinned and Cooper's hawks or

2.5mi in the case of the larger species, e.g. Red-shouldered and Red-tailed hawks.

Habitat Measurements

Vegetation composition and structure and physiographic characteristics were measured at each active nest site on all study areas. Similar measurements were made at randomly selected points in the vicinity (within 16km) of the center of the study areas in Minnesota. Vegetation characteristics were measured within a 0.04ha (0.1ac) circular plot centered on the nest tree. Sampling procedures are described by Titus and Mosher (1981).

STUDY AREAS

The Maryland study areas were located on the coastal plain of Maryland's eastern shore (Wicomico County-1986) largely within the Pokemoke State Forest and on Indian Springs Wildlife Management Area in the Piedmont region of central Maryland (Washington County-1985). The Pokemoke site was generally flat with sandy soils supporting river bottom hardwood forest mixed with plantation and natural conifer stands. The Indian Springs site was contained within a shallow valley with agricultural use typifying the valley floor and mixed hardwood forest of moderate to old age on the hill sides.

The Ohio study areas were located on the Zaleski State Forest (Vinton County-1985 & 1986) nearly adjacent to one another. Both sites were characterized by nearly continuous hardwood forest and moderate relief in a complex array of ridges and steep hillsides. The census routes followed the ridge tops.

There were 5 study areas in Minnesota. The most northern site was in Lake County (1986) on the Superior National Forest within the Boreal Forest. Relief was flat and vegetation consisted of mature red and white pine in thinned stands and birch/aspen/spruce and fir. The area was about 40% cutover. Three other sites were in central Minnesota. The first in Crow Wing and Cass Counties (1986) was flat and marshy covered predominantly by birch/aspen forest. The second, located in Pine county (1985) on the St. Croix State Forest and the third, located in Becker County (1985) on the Smokey Hills State Forest were grossly similar in vegetation and structure to Crow Wing and Cass Counties. Of these four sites, the Pine and Lake county sites and Becker and Crow Wing/Cass county sites had the fewest differences among the pair-wise comparisons of all characteristics measured. These characteristics are primarily structural and physiographic. Floristic differences were apparent, but not measured among the sites. The final site was in the south-east corner of Minnesota in Winona and Wabasha Counties (1987) on the Whitewater Wildlife Management Area. This area was flat, eroded stream bottom with steep hill sides leading up to table land. Vegetation was diverse with mixed hardwoods in the riparian areas and slopes interspersed with marshes and conifer stands. Vegetation was more broken (i.e., open) than the other sites yielding generally better visibility. The Whitwater WMA site more nearly resembled Pine and Lake counties rather than Becker and Crow Wing/Cass counties. Whitewater WMA had the

highest number of large stems (>41cm DBH) and lowest shrub density in the random plots measured. Also, greater relief was evidenced by the greater slope.

Comparable data from two other study sites in Maryland are included in the analyses in this report. Work on both of these sites was conducted during 1983 and 1984. These study sites were located in Garrett County on the Savage River State Forest and in Allegany County on the Green Ridge State Forest. Both areas are within the Appalachian Province and are characterized by mixed mesophytic and oak-chestnut forest covering about 90% of the study areas.

RESULTS AND DISCUSSION

Nesting Density

Density was based on probable numbers of pairs present. It was clear from observational data that pairs were present for which active nests did not exist or could not be found. That is, birds were observed during the breeding season in areas well removed from any known active nest. These pairs may not have attempted to breed, may have made a breeding attempt and failed early before a nest could be found, or the field crew simply failed to find all active nests. The adjustment from actual number of nests found to probable pairs present was based primarily on interpretation of spot maps created from daily field observations. I believe that the estimates are conservative (see Methods).

With only one exception (Pokemoke State Forest) the density of hawk pairs resident on the study areas ranged from 0.6 to 1.4 pair/mi2 the average being 1.0 pair/mi2 (Tables 1a & b). The Pokemoke State Forest study area was unexplainably devoid of any hawk activity. Also, the exceptionally high densities of Broad-winged Hawks on the St. Croix and Smokey Hills study areas are similarly unexplainable. In particular, the absence of other species on the St. Croix study area was curious. There were no apparent unique characteristics of habitat structure or composition which might account for this anomaly, nor did field observations suggest any notable characteristics of prey diversity or abundance. Rosenfield (1984) reported a similarily high Broad-winged Hawk nesting density in Wisconsin. It remains for further studies to account for such variations in hawk nesting density.

Breeding Chronology

Minimal data on hatch date, nest success and productivity were gathered concurrent with other activities. Information from 16 of 47 active nests found on Minnesota study areas is available (Table 2). Hatch dates for most species appear to occur during the first two weeks of June. By back dating then, egg laying should occur about the 1st of May. These dates are relevant to selecting the beginning date for conducting road counts which is discussed below.

Census

Road count data acquired from the standard point count transects were available from 11 different study areas. Two of the sites (Savage River and Green Ridge State Forests were sampled in consecutive years (1983-84). To avoid a possible dependence problem, only the 1984 data were included. Data from the Pokemoke State Forest (MD-1986) were excluded because no nests were found and no contacts were made throughout the season and the level of search effort made at this site may not be comparable to the other sites. Thus, nine (9) pairs of data points (contact rates and probable pairs of Hawks) each for Red-shouldered, Red-tailed, Sharp-shinned and Cooper's hawks were available for analysis. Broad-winged Hawk results from St. Croix and Smokey Hills State Forests were anomalous and discarded as outliers leaving 7 pairs of data points. Each pair of data points represent 7 to 11 replications of the point count transect per season. Contact rates for each species by study area and broadcast vocalization are presented in Tables 3a & b. A comparison of these rates between the Great-horned Owl and Conspecific broadcasts revealed higher rates for both hawk species tested when using the Great-horned Owl broadcast. However, this difference was significant for only the Red-shouldered Hawk (Table 4). Earlier work (Mosher et al. in review) showed that all hawk species respond to Great-horned Owl vocalizations while inter-specific responses to hawk vocalizations are very low.

Significant regression models were found for Broad- winged, Red-shouldered, and Cooper's hawks as well as for all hawk species and all Minnesota study areas (Table 5). These models take the form $Y = bo + b1X$ or $X = [Y - bo]/b1$ where X is the probable number of pairs of hawks resident on the study area and Y is the average number of contacts per transect for each study area.

Because we are interested in predicting the independent variable (number of pairs) from the dependant variable (contact rate), the confidence limits about the regression are asymmetrical (see Draper & Smith 1981 and Neter et al. 1985). Standard error of the estimate (X) and confidence limits are therefore dependant on the value of Y and the number of replications of the transect. Examples of these statistics are given in Table 6. The species models have the higher correlation coefficients and equal or lower standard errors of the estimates compared to either the All Hawk or All MN models (Table 5). However, at the mean number of resident pairs (see Table 6) the All Minnesota model produces the lowest Standard Error and narrowest confidence interval. A review of the average integer error comparisons between the models (Table 7) argues for the use of the All Species model in the case the Broad-winged Hawk. When the objective is to detect differences over time or space, the model giving the lowest standard error and narrowest confidence interval should be selected. Regrettably, there are insufficient data from Maryland and Ohio to examine for differences between

geographic regions. However, I fail to see any substantial reason why such differences should exist within sympatric populations and grossly similar habitats.

Management Applications

This broadcast technique may be used to aid in the detection of woodland hawks during the breeding season in a number of ways. The specific application is dependant on the study objective(s). The following are examples of possible applications for increasingly demanding objectives.

I. The simplest objective would be to determine the presence or absence of one or more nesting species of hawks on a given area. To accomplish this, distribute point counts at a minimum of 0.5mi intervals randomly (or stratified if discontinuities exist in habitat types) along the road system throughout the area ofinterest. The intensity of this sampling, i.e. the density of point count stops, will depend on the availability of count personnel and time. Conduct standard 10-min broadcast counts at each point up to a maximum of 6 times each. Cease to conduct counts at each point when contact is made with the species of interest. At each point count, record the species contacted, the compass bearing from the stop to the contact location, and the approximate distance to the contact. The later information will permit a spot map to be prepared from the point count information. For species smaller than Red-shouldered Hawks

the effective sample area is estimated to be within a 0.5mi radius of the stop and within a 1.0mi radius for Red-shouldered Hawks and larger species. These area differences reflect differences in home range sizes and perhaps behavioral differences between species. The estimates are subjective though based on accumulated data on stop-to-nest distances and estimated distances from stops to contacts. This estimate of effective sample areas may be used as an aid to determining sampling intensity. For example, if you wish to sample 20% of an area, you could distribute point counts along 20% of the linear road distance or divide 20% of the total area by the effective area per point count. More point counts will be required for sampling for the smaller species than for the larger to obtain the same area of coverage.

II. If one is interested in assessing the relative abundance over space or time then fixed point count stops must be established on an area or areas. Each stop should be replicated 6 times per season and average contact rates for each area or season calculated. Comparison of average contact rates between areas or seasons will provide an index to relative abundance. Additional dispersion data may be acquired by again spot-mapping the contacts.

III. An estimate of abundance or population index may be acquired by conducting standard 10-stop point counts (standard route). The results from each route apply only to the 12.5mi2 area surrounding the route. Routes must be replicated 6 times per

season and the statistical parameters presented (Tables 5 & 6) will apply to the results. For State-wide or regional surveys designed to monitor population trends, I recommend the distribution of standard routes following a random or stratified-random sampling scheme. One standard route requires about 15 hours of field effort per season.

Conclusions

The point count method described herein provides the wildlife manager with a tool for surveying and monitoring woodland hawks. Following standard route protocol will provide estimates of abundance of pairs present during the breeding season with estimates of statistical reliability and precision. The specific application of the broadcast technique will vary with management objectives.

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TABLES

Table 1a. Hawk nesting activity on raptor census project study areas in Minnesota 1985 - 1987

Hawk Species	1985 StC	1985 SmH	1986 CW	1986 Lake	1987 WWater	MN Mean
Broad-winged Hawk						
Active Nests	14	11	2	4	1	6.4
Probable Pairs	14	11	5	4	4	7.6
Density[1]	1.2	0.9	0.4	0.3	0.3	0.6(0.18)[2]
Red-shouldered Hawks						
Active Nests	0	4	0	0	4	1.6
Probable Pairs	1	4	0	0	4	1.8
Density	0.1	0.3	0	0	0.3	0.1 (0.06)
Red-tailed Hawks						
Active Nests	0	1	1	2	2	1.2
Probable Pairs	0	2	1	2	2	1.4
Density	0	0.2	0.1	0.2	0.2	0.1
Sharp-shinned Hawks						
Active Nests	0	0	0	0	0	0.0
Probable Pairs	1	0	0	1	0	0.4
Density	0.1	0	0	0.1	0	t
Cooper's Hawks						
Active Nests	0	0	0	0	0	0.0
Probable Pairs	0	0	3	0	1	0.8
Density	0	0	0.2	0	0.1	0.1
Other Species						
Active Nests	0	0	1	0	0	0.2
Probable Pairs	0	0	1	0	0	0.2
Density	0	0	0.1	0	0	t
All Hawks						
Active Nests	14	16	4	6	7	9.4
Probable Pairs	16	17	10	7	11	12.2
Density	1.3	1.4	0.8	0.6	0.9	1.0 (0.15)

[1]Density is given as number of probable pairs per square mile of study area.

[2]Standard error of the mean.

Table 1b. Hawk nesting activity on raptor census project study areas in Maryland and Ohio 1985 & 1986.

	1983		1984		1985		1986		All	
	SR	GR	SR	GR	OH	MD	OH	MD		
Broad-winged Hawk										
Active Nests	5	3	4	3	0	4	3	0	4.3	
Probable Pairs	5	3	4	3	5	7	3	0	5.9	
Density[1]	0.4	0.2	0.3	0.2	0.4	0.6	0.2	0	0.4	(0.09)[2]
Red-shouldered Hawks										
Active Nests	2	5	2	4	2	0	3	0	1.4	
Probable Pairs	2	5	2	4	3	0	3	0	1.7	
Density	0.2	0.4	0.2	0.3	0.2	0	0.2	0	0.2	(0.04)
Red-tailed Hawks										
Active Nests	0	0	1	0	1	0	3	0	1.1	
Probable Pairs	1	0	1	0	2	1	2	0	1.3	
Density	0.1	0	0.1	0	0.2	0.1	0.2	0	0.1	(0.02)
Sharp-shinned Hawks										
Active Nests	0	0	0	1	0	0	0	0	t	
Probable Pairs	0	0	0	1	0	0	0	0	0.2	
Density	0	0	0	0.1	0	0	0	0	t	
Cooper's Hawks										
Active Nests	1	1	4	2	1	1	2	0	0.9	
Probable Pairs	1	1	4	2	2	2	2	1	1.5	
Density	0.1	0.1	0.3	0.2	0.2	0.2	0.2	0.1	0.1	(0.03)
Other Species										
Active Nests	0	0	0	0	0	0	0	0	0.1	
Probable Pairs	0	0	0	0	0	0	0	0	0.1	
Density	0	0	0	0	0	0	0	0	t	
All Hawks										
Active Nests	8	9	11	10	4	5	11	0	8.1	
Probable Pairs	9	9	11	10	12	10	10	1	10.2	
Density	0.7	0.7	0.9	0.8	1.0	0.8	0.8	0.1	0.8	(0.09)

[1]Density is given as number of probable pairs per square mile of study area.
[2]Standard error of the mean.

Table 2. Raptor nesting chronology and productivity in Minnesota, 1985-1987[1]

	Estimated Hatch Date Mean (n)	Number of Young Mean (n) % Success[2]
1985		
St. Croix		
Broad-winged Hawk	6/14 (4)	1.70 (7) 100
Goshawk		1.00 (1)
Smoky Hills		
Broad-winged Hawk	6/17 (5)	1.50 (6) 100
Red-shouldered Hawk	6/3 (2)	1.00 (2) 50
1986		
Lake Co.		
Broad-winged Hawk	6/22 (2)	0.75 (4) 50
Red-tailed Hawk		1.00 (1)
Crow Wing Co.		
Broad-winged Hawk		0.00 (2) 0
Red-tailed Hawk		1.00 (1)
1987		
White Water WMA		
Broad-winged Hawk	6/10 (1)	
Red-shouldered Hawk	5/17 (1)	1.00 (4) 50
Red-tailed Hawk	5/9 (1)	0.50 (2) 50

[1]Data represent the best estimates from field notes recorded during nest visits.

[2]Percent of nesting attempts, with known outcome, that produced at least one young to banding age (2-3 weeks).

Table 3a. Contact rates from road counts conducted from 1985-1987 using broadcasts of Great-horned Owl vocalizations (number of contacts/number of route replications).

	BWH	RSH	RTH	SSH	CH
White Water WMA	4.73 (2.88)[1]	3.36	4.09	0.36 (0.17)	0.27 (0.25)
Crow Wing Co.	1.44 (1.86)	0.00	0.22	0.22 (0.29)	0.33 (0.43)
Lake Co.	1.62 (1.71)	0.00	0.50	0.12 (0.14)	0.00
Smokey Hills SF	1.86 (1.80)	2.29	0.57	0.00	0.00
St. Croix SF	2.11 (1.33)	0.22	0.00	0.78 (0.33)	0.11 (0.00)
Zaleski SF, 1986	0.15 (0.20)	1.46	0.77	0.00	0.31 (0.40)
Zaleski SF, 1985	1.7 (2.3)	2.3	0.0	0.0	0.2 (0.3)
Indian Springs WMA	3.8 (4.5)	0.2	1.3	0.4 (0.0)	0.1 (0.1)
Pokemoke SF	0.00	0.00	0.00	0.00	0.00

[1]Contact rate adjusted to eliminate migrating hawks.

Table 3b. Contact rates from road counts conducted from 1985-1987 using broadcasts of con-specific vocalizations (number of contacts/number of route replications).

Species Broadcast / Study Area / State-Year	Hawk Species				
	BWH	RSH	RTH	SSH	CH
Red-shoulder Hawk					
Whitewater WMA MN-87	1.80 (1.63)[1]	2.20	2.40	0.60 (0.17)	0.00
Crow Wing Co. MN-86	1.29 (0.00)	0.00	1.00	0.14 (0.00)	0.14 (0.17)
Smokey Hills SF MN-85	2.14 (1.83)	0.86	0.14	0.00	0.00
Zaleski SF OH-86	0.00	0.67	0.17	0.00	0.17 (0.22)
Zaleski SF OH-85	0.7 (0.7)	2.6	0.1	0.0	0.1 (0.0)
Cooper's Hawk					
Lake Co. MN-86	0.38 (0.43)	0.00	0.50	0.00	0.00
St. Croix SF MN-85	0.40 (0.20)	0.20	0.00	0.00	0.00
Indian Springs WMA MD-85	4.1 (3.8)	0.0	0.7	2.2 (0.2)	0.7 (0.0)
Pokemoke SF MD-86	0.00	0.00	0.00	0.00	0.22 (0.22)

[1]Contact rate adjusted to eliminate migrating hawks.

Table 4. Comparison of contact rates resulting from paired con-specific and Great-horned Owl Broadcasts, 1985 - 1987.

	Contact rates	
	Cooper's Hawk Hawk[1]	Red-shouldered
Species Broadcast		
Con-specific		
MN-87		2.20
MN-86	0.00	0.00
MN-85	0.00	0.86
OH-86		0.67
OH-85		2.60
MD-86	0.22	
MD-85	0.00	
Mean	0.05 (0.05)[2]	1.27 (0.49)
Great-Horned Owl		
MN-87		3.36
MN-86	0.43	0.00
MN-85	0.00	2.29
OH-86		1.46
OH-85		2.30
MD-86	0.00	
MD-85	0.10	
Mean	0.13 (0.10)	1.91 (0.58)

[1]Significant difference between means based on paired student's-t test at a = 0.05.

[2]Standard error.

Table 5. Linear regression models for predicting number of pairs (X) of hawks based on contact rates (Y) from road counts using Great-horned Owl broadcasts, 1983 - 1987.[1]

Hawk Species (n)	b0(SE)	b1(SE)	MSE[2]	r2	SEest.	P
All (52)	-0.078(0.099)	0.457(0.043)	0.293	0.687	0.541	0.000
Broad-wing (7)	-2.883(0.624)	1.035(0.132)	0.170	0.909	0.412	0.001
Red-shouldered (9)	0.015(0.223)	0.592(0.085)	0.188	0.856	0.433	0.000
Red-tailed (9)	NS					
Sharp-shinned (9)	NS					
Cooper's (9)	-0.031(0.026)	0.146(0.013)	0.003	0.937	0.054	0.000
Goshawk (9)	NS					
MN ALL (28)	-0.027(0.100)	0.448(0.049)	0.174	0.751	0.417	0.000

[1]The regression model y = bo + b1X may be expressed as X = [Y + bo]/b1.

[2]Mean square error.

Table 6. Example statistics for regression models assuming a) six (6) replications of each route and b) the average contact rate for the species or species group, and where the model is expressed as X = [Y + bo]/b1.

Species	Standard error of the estimate (X)	Mean no. pairs (X)	Confidence limits (90%)
Broad-winged Hawk	+ 0.402	4.57	+1.23
Red-shouldered Hawk	+ 0.267	2.00	+0.96
Cooper's Hawk	+ 0.023	1.44	+0.30
All MN species	+ 0.001	1.25	+0.04

Table 7. Number of probable resident pairs of hawks on the Minnesota study areas compared to the number of pairs predicted from the regression model(s).

Study areas	Species				
	BW	RS	RT	SS	CH
1987					
Whitewater WMA					
Probable	4	4	2	0	0
Predicted:					
Species model	0	5.9	na	na	1.5
All MN species	5.8	7.2	-	0	0
All species	6.1	7.5	-	0.2	0.4
1986					
Crow Wing Co.					
Probable	5	0	1	0	3
Predicted:					
Species Model	0	0	na	na	2.0
All MN species	3.5	0	0	0	0.4
All species	3.9	0	0.3	0.5	0.8
Lake Co.					
Probable	4	0	2	1	0
Predicted:					
Species model	0	0	na	na	0
All MN species	0.6	0	0.5	0	0
All species	3.6	0	1.0	0.1	0
1985					
St.Croix SF					
Probable	14	1	0	1	0
Predicted:					
Species model	-	1.9	na	na	0
All MN species	2.4	0	0	0.1	0
All species	2.7	0.3	0	0.6	0
Smokey Hill SF					
Probable	11	4	2	0	0
Predicted:					
Species model	-	3.9	na	na	0
All MN species	3.4	4.5	0.7	0	0
All species	3.8	4.8	1.1	0	0
Average integer error					
Species model	4.3	0.6	na	na	0.4
All MN species	2.2	0.8	1.0	0.2	0.4
All species	1.2	1.0	0.7	0.5	0.4

APPENDIX I. HABITAT DATA AND EVALUATION

It is important to maintain some perspective on the interpretation of the habitat data which follow in this section. The determination of selection for certain characteristics of habitat by any species is dependant on sampling methods.

First, I have defined selection as the difference between use and availability of a given feature measured by the same technique(s). For example, if we randomly sample a forest and find it is composed of a normal distribution of trees with respect to canopy height, with a mean height of 18.0m, and the same measurement taken at hawk nest sites is 24.0m we impute selection on the part of the hawks for a higher canopy height than is generally available. However, if our sampling of the forest included very small sapling stands with trees too small to support a hawk nest, then our mean of 18.0m is biased on the low side and hawks may not be selecting taller trees from that which are truly available. Which is to say that our sampling of the forest included stands that were not available to the birds for nesting use. The opposite error is equally easy to make by sampling only old age stands of the forest which could result in showing no selection for higher canopy heights when selection did occur. This is not a trivial example, as I used in this study and others, a minimum canopy height as a requisite for accepting random plots. The minimum used was the lowest measured canopy height at hawk nests sampled throughout the northeast (MD, PA, CT, NY, and WI).

Second, some characteristics such as "distance to the nearest water" are highly variable and consequently sample sizes needed for statistical reliability are large (Mosher et al. 1986). In many instances, the minimum sample sizes required to be within 20% of the mean for 95% of the samples were not achieved in this study.

Despite the problems and cautions, comparison of hawk nest sites with the random samples reveal general concurrence with other similar studies. The summaries and data given below should provide useful guides to land managers for identifying potential nesting habitat for these species.

Random Habitat

Twenty-five plots were randomly selected within 10km of the center of each study area and were sampled for the same characteristics as measured at hawk nest sites. The similarity between study areas (Table A1) for all characteristics reflects, in part, our selection of study sites that appeared to be grossly suitable nesting habitat for hawks. Areas which were less than 70% forested were avoided as were pole stage and/or scrub forests. These data provide the description of "available habitat" against which the hawk nest sites are compared.

Broad-winged Hawks

Thirty-three Broad-winged Hawk nest sites were sampled (Table A2). Few differences from the random data can be found.

Broad-wings nest almost at random throughout the forest. Although, there is a tendency for sites to be selected near ponds and small steams. Management which retains a majority of forest cover in age classes beyond pole stage, especially around well watered areas will be beneficial to this species. For undetermined reasons, the St. Croix and Smokey Hills study areas were apparently prime habitat for Broad-winged Hawk nesting. The nesting densities observed on these areas are the highest reported with the single exception of Rosenfield's (1984) Wisconsin study area. Although the slightly higher density he reported can be accounted for by differences in methodology. He search his area foe nests then defined the study area boundaries. We defined the boundaries first.

Red-shouldered Hawks

Red-shouldered Hawk nests were found on only two study areas, although they were observed regularly in the vicinity of the St. Croix study area. The densities on Smokey Hills and Whitewater study areas are indicative of good nesting habitat. The highest density I have observed (1 pair per 20.8mi^{1}) occurred on one of the Maryland study areas.

Nest sites are characterized by older aged timber. The stem count in the <21cm size class is low and overstory cover is high. Though it wasn't clearly reflected on the Whitewater area, this species invariably nests close to water. Large diameter nest

trees (eg. >40cm DBH) within 100m of streams, rivers and ponds are consistently selected.

Red-tailed Hawks

Very tall, large diameter trees in more open areas of the forests are selected by Red-tailed Hawks. These trees usually stand apart or extend above the surrounding canopy. Physical access to the nest by this relatively large and less agile hawk appears to influence site selection. Canopy height at Red-tail sites was consistently higher than the random plots and overstory stem counts were very low. The resulting open canopy also produces high shrub densities. Red-tails also tend to be found on or near ridge tops which dissociates them from most types of water and, again provides for easier access to the nest. This topographic placement of the nest site may also provide ready access to updraits commonly used by this soaring species.

Table A1. Habitat characteristics of randomly selected plots in Minnesota 1985 - 1987.

	Random Plots (n=25 per study area)				
	St. Croix	Smokey Hls	Crow Wing	Lake	Whitewater
Canopy Height(m)	17.4[1] (0.4)	18.7 (0.8)	20.1 (0.6)	17.5 (0.9)	18.7 (0.7)
Basal Area(m^2/ha)	15.2 (0.7)	15.6 (1.6)	18.9 (1.6)	16.7 (1.2)	21.6 (1.5)
No Stems <21cm	6.4 (1.7)	10.4 (2.4)	15.9 (2.5)	9.6 (2.4)	3.5 (0.7)
No Stems 21-41cm	7.4 (0.7)	7.0 (1.1)	9.3 (0.9)	8.1 (1.6)	10.7 (2.6)
No STems >41	0.4 (0.2)	0.2 (0.1)	0.1 (0.1)	0.4 (0.2)	1.5 (0.3)
Shrub Density	56.3 (10.4)	159.7 (23.2)	181.2 (27.5)	69.8 (13.4)	11.0 (1.4)
Overstory Cover(%)	77.0 (3.8)	73.6 (4.5)	72.0 (3.9)	69.8 (3.5)	85.3 (2.5)
Understory Cover(%)	24.4 (5.0)	43.2 (4.2)	44.6 (4.5)	24.1 (4.4)	55.6 (4.7)
Ground Cover(%)	74.9 (3.1)	100.0 (0.0)	99.9 (0.0)	46.9 (3.0)	76.7 (3.3)
No Tree Species	2.0 (0.2)	2.8 (0.3)	3.8 (0.3)	2.4 (0.2)	3.3 (0.3)
Dist. To Water(m)	172.2 (22.6)	398.4 (22.6)	411.6 (74.6)	231.2 (27.6)	180.0 (9.7)
Dist. To Opening(m)	65.6 (7.9)	126.6 (34.3)	268.6 (69.4)	73.4 (15.9)	40.8 (5.0)
Slope(%)	2.2 (0.4)	1.2 (0.6)	1.6 (0.7)	5.3 (1.2)	15.9 (2.6)

[1]Mean/(SE).

TABLE A1. Habitat characteristics of hawk nest sites in Minnesota, 1985 through 1987.

	BROAD-WINGED HAWK								
	St. Croix (15)		Smokey Hills (11)		Lake Co (4)		Crow Wing Co (2)		White Water (1)
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Nest Height	9.60	2.81	11.10	3.60	8.90	2.10	10.60	1.24	12.00
Nest Tree Height	21.40	4.20	19.50	4.70	18.00	2.84	25.70	0.25	18.50
% Nest Height	46.00	14.20	59.00	15.50	50.10	8.30	41.00	4.50	64.90
DBH Nest Tree	33.90	5.30	32.80	5.60	38.30	5.03	29.50	3.00	28.70
Canopy Height	20.00	1.90	21.20	2.50	18.50	2.46	20.20	2.45	19.70
Basal Area	15.30	3.90	13.60	4.30	24.90	5.66	16.60	3.85	9.70
No Stems (21cm	11.00	8.00	5.00	6.00	2.50	0.87	0.00	0.00	4.00
No Stems 21-41cm	8.00	3.00	7.00	3.00	7.50	0.65	8.00	1.00	5.00
No Stems)41cm	0.00		1.00	1.00	1.20	0.75	0.00	0.00	0.00
Shrub Density	116.00	43.00	173.00	149.00	92.50	23.03	187.50	13.50	22.00
Overstory Cover (%)	73.00	23.00	69.00	8.00	77.00	8.26	99.00	0.50	93.00
Understory Cover(%)	63.00	18.00	54.00	16.00	26.50	13.47	82.50	2.50	53.00
Ground Cover (%)	75.00	11.00	54.00	24.00	50.30	7.15	100.00	0.00	95.00
No Tree Species	4.00	1.30	3.50	0.90	3.80	0.75	3.50	1.50	4.00
Dist. To Water	97.00	96.00	24.00	57.00	123.00	59.00	500.00	0.00	300.00
Dist. To Opening	97.00	81.00	148.00	51.00	86.20	39.55	365.00	25.93	15.00
Slope (%)	1.00	3.70	4.00	7.90	4.30	1.38	0.00	0.00	35.00

TABLE A2. Habitat characteristics of hawk nest sites in Minnesota, 1985 through 1987.

	RED-SHOULDERED HAWK					
	St. Croix	Smokey Hills (4)		Lake Co	Crow Wing Co	White Water (4)	
		Mean	SE			Mean	SE
Nest Height		16.00	1.30			12.60	1.43
Nest Tree Height		25.50	1.50			21.50	1.37
% Nest Height		63.00	4.00			58.60	4.90
DBH Nest Tree		40.20	4.00			57.20	5.10
Canopy Height		25.30	1.60			17.50	1.00
Basal Area		19.00	3.10			16.20	3.00
No Stems (21cm		2.00	1.00			0.50	0.50
No Stems 21-41cm		8.00	3.00			1.80	1.10
No Stems)41cm		1.00	1.00			2.50	0.50
Shrub Density		498.00	128.00			2.30	1.40
Overstory Cover (%)		84.00	9.00			73.30	8.50
Understory Cover(%)		80.00	9.00			24.50	10.90
Ground Cover (%)		7.00	3.00			87.80	5.50
No Tree Species		4.50	1.10			2.00	0.40
Dist. To Water		83.00	36.10			158.80	91.30
Dist. To Opening		100.00	72.90			43.80	20.80
Slope (%)		7.50	7.50			1.80	1.20

TABLE A3. Habitat characteristics of hawk nest sites in Minnesota, 1985 through 1987.

	RED-TAILED HAWK					
	St. Croix	Smokey Hills (1)	Lake Co (2)		Crow Wing Co (1)	White Water (4)
		Mean	Mean	SE	Mean	Mean SE
Nest Height		19.00	17.60	0.75	15.00	15.10 1.70
Nest Tree Height		25.00	20.00	2.80	17.00	25.90 2.85
% Nest Height		76.00	88.90	8.70	88.20	58.30 8.30
DBH Nest Tree		53.80	43.80	6.00	46.40	62.10 15.49
Canopy Height		24.60	19.90	2.00	18.20	24.10 1.35
Basal Area		23.20	15.70	1.95	24.20	25.40 7.50
No Stems (21cm		0.00	0.50	0.50	7.00	0.00 0.00
No Stems 21-41cm		2.00	7.50	3.50	10.00	3.00 3.00
No Stems)41cm		4.00	2.00	2.00	1.00	3.00 0.00
Shrub Density		265.00	91.00	5.00	171.00	119.00 2.05
Overstory Cover (%)		63.00	71.50	11.50		98.00 12.02
Understory Cover(%)		0.00	4.00	4.00	0.00	56.50 15.49
Ground Cover (%)		48.00	62.50	2.50	100.00	75.00 7.78
No Tree Species		3.00	2.00	4.50	3.00	2.50 0.57
Dist. To Water		25.00	305.00	245.00	5.00	200.00 100.00
Dist. To Opening		0.00	20.00	0.00	100.00	112.50 61.87
Slope (%)		0.00	4.50	2.50	0.00	15.50 1.67

TABLE A4. Habitat characteristics of randomly selected plots in Minnesota, 1985 through 1987.

	RANDOM PLOTS (n=25 per study site)									
	St Croix		Smokey Hills		Crow Wing Co		Lake Co		White Water	
	mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Canopy Height	17.40	0.40	18.70	0.77	20.10	0.60	17.50	0.90	18.70	0.74
Basal Area	15.20	0.70	15.60	1.61	18.90	1.56	16.70	1.23	21.60	1.54
No Stems (21cm	6.40	1.70	10.40	2.36	15.90	2.48	9.60	2.40	3.50	0.71
No Stems 21-41cm	7.40	0.74	7.00	1.07	9.30	0.93	8.10	1.57	10.70	2.58
No Stems)41cm	0.40	0.18	0.20	0.10	0.10	0.07	0.40	0.17	1.50	0.34
Shrub Density	56.30	10.39	159.70	23.20	181.20	27.45	69.80	13.35	11.00	1.36
Overstory Cover (%)	77.00	3.80	73.60	4.45	72.00	3.94	69.80	3.46	85.30	2.54
Understory Cover(%)	24.40	4.97	43.20	4.23	44.60	4.49	24.10	4.40	55.60	4.72
Ground Cover (%)	74.90	3.10	100.00	0.00	99.90	0.00	46.90	3.00	76.70	3.30
No Tree Species	2.00	0.20	2.80	0.33	3.80	0.30	2.40	0.20	3.30	0.26
Dist. To Water	172.20	22.62	398.40	22.61	411.60	74.57	231.20	27.60	180.00	9.72
Dist. To Opening	65.60	7.94	126.60	34.34	268.60	69.43	73.40	15.90	40.80	5.01
Slope (%)	2.20	0.38	1.20	0.59	1.60	0.73	5.30	1.20	15.90	2.58

Habitat Data File: 1987, Minnesota, Whitewater WMA

Sp	Cnht	Basal	ST<21	ST2141	ST>41	ShrbD	OCov	UCov	GCov	Water	Open	Slp[1]
Broad-winged Hawk												
11	197	97	4	5	0	22	93	53	95	300	15	35
Red-snouldered Hawk												
12	172	237	0	1	4	0	60	0	100	25	10	0
12	203	137	0	0	2	0	65	20	83	200	50	0
12	167	178	0	5	2	3	98	25	93	10	15	2
12	159	97	2	1	2	6	70	53	75	400	100	5
Red-tailed Hawk												
13	254	179	0	0	3	238	98	88	55	300	200	30
13	227	329	0	6	3	0	98	25	95	100	25	1
Random Plots												
99	168	182	5	2	3	2	88	73	68	400	25	10
99	156	169	0	4	2	5	93	25	95	200	25	4
99	123	192	0	10	0	13	68	68	55	25	50	22
99	175	165	13	70	0	23	100	60	100	400	25	2
99	237	297	9	16	0	27	78	65	80	100	50	14
99	203	143	1	7	1	8	73	25	98	100	100	33
99	185	330	1	10	3	9	95	68	58	300	25	23
99	199	438	3	10	5	18	98	68	48	300	25	18
99	157	262	8	12	0	11	88	60	88	200	25	24
99	193	179	9	11	0	7	98	60	60	400	20	10
11	257	305	0	6	5	13	55	90	80	50	25	2
99	215	133	2	7	0	11	90	78	63	500	25	10
99	192	197	5	4	2	4	83	63	90	25	25	2
99	189	219	0	13	1	4	73	43	93	25	25	26
99	181	275	5	18	0	24	90	83	53	150	50	55
99	164	184	1	6	1	16	100	63	70	200	50	10
99	182	323	0	4	4	15	88	15	83	300	50	20
99	187	189	2	6	2	5	88	63	55	25	25	25
99	158	170	8	8	1	17	100	78	78	200	100	36
99	211	157	3	10	0	5	58	0	100	20	25	1
99	226	150	2	7	1	8	100	35	95	25	25	10
99	106	99	5	7	0	5	80	20	75	200	50	11
99	199	172	4	10	0	7	75	50	95	300	50	4
99	270	219	0	6	3	5	85	85	70	50	25	5
99	154	245	2	4	4	13	88	53	68	5	100	20

[1]Cnht, Basal given as x.x meters; St<21-SrbD given as counts; UCov-GCov & Slp given as %; distance to nearest Water and Open given as x meters.

Habitat Data File: 1987, Minnesota, Whitwater WMA

Species	Nest #	Nest Hgt (x.x m)	Co.	DBH (x.x m)	TreeHgt (x.x m)	Loc.	Cond.
Broad-winged Hawk							
11	7	120	Win	287	185	1	2
Red-shouldered Hawk							
12	2	117	Win	569	210	2	5
12	3	135	Win	659	245	2	2
12	4	140	Win	630	225	2	4
12	5	110	Win	429	180	1	10
Red-tailed Hawk							
13	1	168	Win	511	230	1	2
13	6	134	Win	730	287	2	5
Random Plots							
99	1		Win	291	175		1
99			Wab	331	170		1
99			Wab	321	135		2
99			Win	326	200		10
99			Win	313	270		5
99			Wab	344	245		2
99			Wab	292	232		5
99			Win	358	190		5
99			Wab	332	172		1
99			Win	372	220		2
99			Win	420	308		3
99			Wab	340	216		1
99			Wab	361	205		1
99			Win	324	175		10
99			Win	232	110		0
99			Win	198	160		0
99			Win	592	210		2
99			Win	434	227		3
99			WIN	314	155		1
99			Win	360	220		5
99			Win	284	245		0
99			Olm	264	105		2
99			Win	301	200		0
99			Olm	435	360		0
99			Win	485	133		1