Ecological Relationships of Accipiters in Northern Utah - With Special Emphasis on the Effects of Human Disturbance

Stephen P. Hennessy
Utah State University

ECOLOGICAL RELATIONSHIPS OF ACCIPITERS IN NORTHERN UTAH - WITH SPECIAL EMPHASIS ON THE EFFECTS OF HUMAN DISTURBANCE

by

Stephen P. Hennessy

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Due to the untimely death of Stephen Hennessy near the completion of this Master's Degree, he was unable to credit those who helped him in his work on this degree. Had he been able to write this section, his wife, Katie, would have headed this list of acknowledgments. Her encouragement and interest in his project undoubtedly was a major motivation in helping him carry out this work.

Assistance on the statistical analysis of this thesis was provided by Dr. Rex L. Hurst, Head, Department of Applied Statistics and Computer Science; and David Iverson and Ali Malek, graduate students in statistics.

Steve's unique and genuine interest in birds of prey was a driving force that kept him going even though this project was without financial backing. It is this sort of dedication and interest that separates the real biologist from those who may enjoy nature but give only token service to trying to understand it.

Dr. Gar W. Workman
Major Professor

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ABSTRACT

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by

Stephen P. Hennessy, Master of Science

Utah State University, 1978

Major Professor: Dr. Gar W. Workman
Department: Wildlife Science

The purpose of this study was to examine the effect of habitat parameters and human disturbance on the nesting success of goshawks, Cooper's hawks, and sharp-shinned hawks in an area within the Cache National Forest of Utah and Idaho. This research should provide the wildlife manager with information of value in planning recreation areas, roads, timber cuttings, and other activities where impacts are considered.

Of the three accipiter species studied, the goshawk showed the greatest preference for isolation from man. It nested at higher elevations ($\overline{X}$ = 2,065 m); farther from human disturbance ($\overline{X}$ = 250 m); higher in trees ($\overline{X}$ = 12 m); farther into cover ($\overline{X}$ = 55 m) [generally in a mature forest]; and in proximity to water ($\overline{X}$ = 394 m) with considerable horizontal visibility from the nest ($\overline{X}$ = 53 m). The average number of young fledged from goshawk nests was 1.4.

The nesting Cooper's hawk was more tolerant to human disturbance ($\overline{X}$ = 147 m); nested closest to water ($\overline{X}$ = 220 m); at moderate elevation

($\overline{X}$ = 1,782 m); and in an average of 8 m above ground. Their range overlapped that of recreational activities and also that of sharp-shinned hawks. Cooper's hawks fledged an average of 1.6 young per nest.

The sharp-shinned hawks nested farthest from water ($\overline{X}$ = 444 m); at about the same elevation as Cooper's hawks ($\overline{X}$ = 1,789 m); closer to human disturbance ($\overline{X}$ = 161 m); closer to the ground ($\overline{X}$ = 6 m); and in nests with short horizontal visibility ($\overline{X}$ = 14 m). The sharp-shinned hawks fledged an average of 2.1 young per nest.

As a general rule, all of the accipiters studied preferred to nest on the lower part of a north-facing slope with a well-developed tree canopy. Goshawks appeared to be most sensitive to man, while the Cooper's and sharp-shinned hawks were similar in habitat requirements and had nesting sites in closer proximity to human activities.

(66 pages)

INTRODUCTION

In recent years an increasing amount of research has focused on various species of raptorial birds, and on factors which influence their biology and numbers. One factor which has been insufficiently studied is the effect of human activities on raptor nesting sites.

The goshawk (Accipiter gentilis), Cooper's hawk (A. cooperii), and sharp-shinned hawk (A. striatus) are restricted in their breeding range to areas with woodland or forest growth. This growth must be sufficient to provide the sheltered nesting sites they prefer. The vegetation, water, and other physical factors which attract nesting accipiters also tend to concentrate outdoor recreational activities in canyons and mountain valleys, particularly in parts of the western United States, where prime woodland growth may be quite discontinuous. This situation can lead to frequent encounters between nesting accipiters and man. The purpose of the project was to study the extent to which recreational activities affect the productivity of accipiter hawks in a Utah forest area.

REVIEW OF LITERATURE

Much of the literature dealing with the goshawk, Cooper's hawk, and sharp-shinned hawk consists of isolated accounts of nesting occurrences. Among these are the accounts of Baumgartner (1938), Eliot (1948), Grome (1935), Ray (1926), and others on the goshawk; Fitch et al. (1942) on the Cooper's hawk; and Rust (1914) on the sharp-shinned hawk. Schnell's (1958) paper on nesting and food habits of California goshawks and Meng's (1951) dissertation on the Cooper's hawk are two of the more important general works.

Literature dealing with nesting success of raptors as related to human disturbance is scarce. Two articles of particular relevance to this study are those by Mathisen (1968) and Grier (1969). Mathisen's study attempted to quantify the effects of human disturbance on bald eagles, Haliaeetus leucocephalus, breeding in the Chippewa National Forest in Minnesota. Disturbance was rated as high, medium, or low with respect to eagle nests, depending upon the presence or absence of five specified disturbance criteria. A statistical comparison of the productivity of nests within each of the three categories was made. Mathisen's conclusion was that human disturbance was not an important factor in lowering the reproductive success of bald eagles in his study area. However, as Mathisen points out, disturbance in the area did not occur until late in the breeding cycle, a time when it would have the least effect on the breeding eagles. Not only did Mathisen feel that earlier disturbance in the area would probably have been harmful, but also that the sensitivity of other species probably differed enough to warrant further study.

In the second study, also dealing with bald eagles, Grier (1969) attempted to determine the effect of climbing a nest tree (to assess its content) on reproductive success. He divided his study nests into two groups, the first to be studied from a distance and the second to be climbed once during the breeding season. From his observations, Grier concluded that climbing the nest tree once during the breeding season did not affect the productivity of the nest. He made an interesting point by suggesting that birds already subjected to considerable disturbance may adapt and not be bothered by someone climbing to the nest. Conversely, the ascent to the nest may be the proverbial last straw, causing the pair to abandon the site.

A recent attempt to evaluate the effect of human disturbance on raptor nesting in Germany was made by Latzel (1972). He described the effects of changing landscapes and disturbance by recreationists on the numbers and species of birds of prey nesting in the district. Latzel concluded that the disappearance of the goshawk and sparrowhawk (Accipiter nisus), among others, was related to these factors.

OBJECTIVES

The objectives of this study were as follows:

1. To study the extent to which human recreational activities are detrimental to the productivity of accipiter hawks in the study area.

2. To evaluate possible differences in sensitivity to disturbance between accipiter hawks nesting near areas of high human activity and those nesting in more remote areas.

3. To gain a clearer understanding of what physical characteristics (e.g. tree size, proximity to water) are necessary for suitable nest sites for accipiter hawks in the study area.

4. To test the effectiveness of recorded accipiter calls as a method of locating or censusing breeding pairs of accipiter hawks.

METHODS

Study Area

The Cache National Forest extends for nearly 250 km, on a north-south axis, from southern Idaho into northern Utah. This area contains the northern end of the Wasatch mountains and the Bear River Range, which are traversed by numerous canyons extending east and west from a central ridge of mountains. Within the National Forest boundaries, elevations vary from about 1,525 m (5,000 ft) up to nearly 3,050 m (10,000 ft), providing a wide variety of habitats. Besides recreational uses, these forest lands support some livestock grazing, timber production, and are an important component of the watershed for cities and agricultural valleys (Figure 1).

The Cache National Forest provides an ideal setting for this study because of the large number and variety of recreation sites, and because of the large populations of resident accipitrine hawks. There are 28 official recreation areas on the Cache Forest, comprising a total of 65 improved recreation sites. These sites are located in a variety of habitats at various elevations. There is also a good gradation in the degree and timing of use, as well as in the quality of access roads to these various sites. Of prime importance to this study is the fact that water is present at 55 (85%) of the recreation sites usually in the form of a stream or river. Such water sources seem to be a major factor in attracting nesting accipiters. Another factor of importance is that the Cache Forest has numerous canyons with no access roads, and

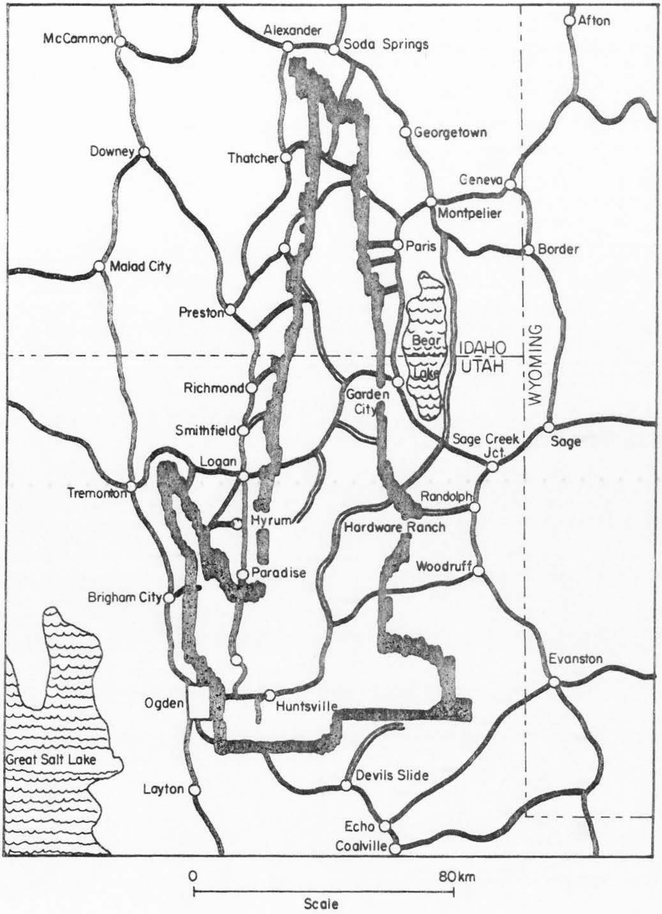

Figure 1. The accipiter study area on the Cache National Forest, Utah-Idaho.

subsequently, little or no recreational use. These are important in providing a control situation for the study.

Data Collection

During the spring and summer, areas which appeared to be suitable accipiter nesting habitat were searched on foot. Locations of new and old nests were noted, as well as other signs of the presence of accipiters such as hunting perches, molted hawk feathers, and fresh kill sites. Courtship activities such as calling and conspicuous midmorning display flights also were noted. By utilizing these observations, a list of active accipiter nests was developed (Table 1).

It was thought that the type of disturbance most likely to lead to reproductive failure was activity immediately adjacent to the nest grove or within sight of the nest itself. Therefore, active nests were classified as to the probability of activity occurring within the nest grove. Three subjective categories for disturbance were used: high, medium, and low. Nests in the high disturbance category were located in the same grove of trees as a campground, or along a trail leading from one campground to another. Nests in the medium disturbance category were located near centers of activity such as campgrounds or roads but were isolated by some physical feature such as a river or a difference in height (i.e. nest located up a steep hillside). Although subject to noise from various sources (passing autos, etc.), nests in this category were unlikely to have actual activity within the nest grove. The low disturbance category included nests which were not located near roads, campgrounds, or other centers of activity. A summary of this information is presented in Table 1.

Table 1. The number of young accipiters fledged by county, site, and disturbance category on the Cache National Forest, Utah-Idaho, study area (1973-1974).

Nest number	County	Location	Nesting grove composition	Disturbance category	Number of young fledged
G-1	Franklin, Idaho	Beaver Creek	lodgepole pine*	high	3
G-2	Cache, Utah	North Fork	lodgepole pine*	medium	2
G-3	Cache, Utah	Tony Grove	aspen, spruce* fir	medium	2
G-4	Cache, Utah	Juniper Trail	aspen* spruce, fir	high	1
G-5	Cache, Utah	Wood Camp Hollow	aspen*	high	2
G-6	Cache, Utah	High Creek	cottonwood* douglas fir	high	2
G-7	Cache, Utah	Paradise Dry	aspen* spruce, fir	low	0
G-8	Box Elder, Utah	Mantua	aspen*	high	1
G-9	Cache, Utah	Amazon Hollow	douglas fir* lodgepole	medium	2
G-10	Cache, Utah	Cowley's Canyon	aspen* douglas fir	medium	0
C-1	Cache, Utah	Sherwood Hills	maple* aspen	low	0
C-2**	Cache, Utah	Mendon	maple*	low	0
C-3	Cache, Utah	Clarkston	maple*	low	3
C-4	Cache, Utah	logan Dry	aspen*	high	0
C-5	Cache, Utah	Oxkiller Hollow	maple*	high	4
C-6	Cache, Utah	Cherry Creek	maple*	medium	3
C-7**	Cache, Utah	Card Picnic	douglas fir*	medium	2
C-8	Cache, Utah	Hyrum Dry	maple*	medium	2
C-9	Cache, Utah	Chicken Creek	maple*	low	1
C-10	Rich, Utah	Sunrise	aspen, pine* spruce	low	0
C-11	Cache, Utah	Blacksmith Right Fork	maple*	medium	4
C-12	Cache, Utah	Blacksmith Left Fork	maple*	high	4
C-13**	Cache, Utah	Providence Canyon	maple*	medium	1
C-14	Utah, Utah	Hobble Creek	maple*	medium	4
C-15	Cache, Utah	Blacksmith Mouth	maple*	high	0
SS-1	Cache, Utah	Wellsville South	maple* choke-cherry	low	3
SS-2	Cache, Utah	Summit Creek Campground	maple, juniper*	high	3
SS-3	Cache, Utah	Blacksmith Left Fork	maple, douglas fir*	medium	4
SS-4	Cache, Utah	Wellsville	maple*	medium	0
SS-5	Cache, Utah	Leatham Hollow	maple, douglas fir*	medium	3
SS-6	Cache, Utah	Summit Creek South Fork	maple, aspen, fir*	low	4
SS-7	Box Elder, Utah	Sardine Summit	maple, oak, juniper*	medium	0

G = goshawk
C = Cooper's hawk
SS= sharp-shinned hawk

* Indicates nest tree species, i.e. aspen
**Immature female nesting

Detailed field notes were made for every nest site visit, and at the end of the study, individual birds were assigned an aggressiveness rating based on their reaction to human approach. The following scale was adopted: 1) shy, disappeared at approach of observer; 2) cackled, then disappeared; 3) remained sitting on nest; 4) cackled and stayed in nearby trees; 5) stooped one or more times at observer. Although the aggressiveness of an individual bird may vary somewhat during the breeding cycle, its relative rating is remarkably constant. In other words, a shy bird may become somewhat more aggressive toward the end of the cycle; however, it remains relatively shy.

Response to vocalization was evaluated using both the observer's imitations and calls recorded from captive birds and from phonograph records.

In a comparison of four quantitative methods of habitat description, James and Shugart (1970) found that area methods tended to be more accurate than plotless methods such as the wandering quarter technique of Catana (1963). They recommended 0.045 ha (0.1 acre) circular plots for use in conjunction with the Audobon breeding bird census as being the most accurate method for the amount of time expended. In this study, a 15 m x 25 m rectangular plot was chosen (Daubenmire and Daubenmire, 1968). This plot was oriented with the longest dimension following the contour of the ground and including the nest tree. All trees in the plot with diameters (breast height) greater than 5 cm (2 in) were measured using a biltmore reach stick (Forbes, 1955) and assigned to size classes. The total number of trees on the plot (stem density) was subsequently adjusted for the slope of the ground to yield a stem density based on a horizontal plot.

Canopy cover was quantified with 50 random observations through a vertical tube to determine either the presence or absence of foliage (James and Shugart, 1970). Ocular estimates were also made of average horizontal visibility in the nest area (from the base of the nest tree) and percentage of ground cover. The average distance at which the nest was visible from the ground was determined and the percentage visibility from the nest itself was roughly quantified by estimating the percentage of a 360° arc which was clear for at least a 3-meter radius from the nest. The classification format used for the collection of data is presented in Table 2.

Whenever possible, infertile eggs and/or broken eggshells were collected for pesticide analysis and shell thickness measurements. Pesticide analysis was performed by Dr. Noel Snyder (Appendix A), and Helen Snyder kindly made the shell thickness measurements on the 1973 samples (Appendix B); 1974 measurements were made by the investigator. To minimize variability due to individual shell thickness, only shell fragments from the equatorial region of the egg were measured.

Table 2. Classification format used in the statistical analysis program for the description of accipiter hawk habitat on the Cache National Forest, Utah-Idaho.

Variable	Unit and Range
Hawk species	3 (each)
Nest distance to cover edge	0 - 244 (meter)
Nest distance to water	0 - 1,829 (meter)
Elevation at nest site	1,433 - 2,469 (meter)
Nest site to human disturbance	0 - 1,143 (meter)
Nest tree diameter	12.7 - 88.9 (centimeters)
Average tree diameter in nest area	12.7 - 88.9 (centimeters)
Nest height above ground	2.4 - 18.9 (meter)
Horizontal visibility in nest area	6.1 - 121.9 (meter)
Nest visibility	3.0 - 91.4 (meter)
Total basal tree diameters/acre	0 - 92.9 (square meter)
Number of young fledged	0 - 5 (each)
Percentage ground cover in nest area	0 - 100 (percent)
Percentage nest visible	0 - 70 (percent)
Percentage tree canopy in nest area	30 - 98 (percent)
Percentage slope at nest site	0 - 75 (percent)
Degree of human disturbance	low, medium, high
Nest location related to canopy	above, in, below
Nest location related to slope	top, middle, lower
Sub-canopy in nest area	absent, slight, moderate, well developed
Barriers between nest and disturbance	absent, slight, moderate, well developed
Aggressiveness of adults	1 = negative, to 5 = high
Slope exposure or flat	north, east, south, west, flat

STATISTICAL ANALYSIS

The main objective of this analysis was to make a statistical evaluation of information from various quantitative variables for three species of accipiterine hawks. This analysis is used to study the degree of similarity or dissimilarity of habitat requirements and behavioral characteristics between these three species.

The following statistical methods were used to analyze the data (Hurst, 1972):

1. Determination of sample means and standard deviations.
2. Discriminant function analysis (15 variables).
3. Orthogonal discriminant function analysis (15 variables).
4. Principle component factor analysis (14 variables).
5. Canonical correlation analysis (13 variables).
6. Multiple regression analysis (22 variables).

Sample Means and Standard Deviations

Means and standard deviations were calculated for each of the 15 habitat parameters measured for each of the three hawk species (Table 3). An examination of these statistics point out the following characteristics.

1. Goshawks and sharp-shinned hawks characteristically nest further into cover than Cooper's hawks (variable 1).

2. Cooper's hawks typically nest closer to water than either sharp-shinned hawks or goshawks.

3. Goshawk nests are located about 30 m higher, on the average, than the other two species.

Table 3. Sample means ($\overline{X}$) and standard deviations (SD) for 14 habitat parameters of three species of accipiter hawks on the Cache National Forest.

Variable	Goshawk $\overline{X}$	Goshawk SD	Cooper's hawk $\overline{X}$	Cooper's hawk SD	Sharp-shinned $\overline{X}$	Sharp-shinned SD	Pooled Information $\overline{X}$	Pooled Information SD
1. Nest distance to cover edge (m)	56.57	62.30	33.77	32.80	50.84	57.06	44.38	49.38
2. Nest distance to water (m)	399.90	333.09	223.72	360.33	451.47	545.96	325.86	405.84
3. Elevation at nest site (m)	2098.24	197.08	1810.82	210.22	1818.04	258.62	1901.04	252.19
4. Nest site to human disturbance (m)	253.59	226.59	149.78	174.25	163.86	221.80	184.77	204.55
5. Nest tree diameter (cm)	33.53	15.32	25.40	11.10	27.33	13.49	28.32	13.33
6. Average tree diameter in nest area (cm)	23.77	4.67	15.47	4.80	14.20	4.65	17.75	6.20
7. Nest height above ground (m)	12.61	3.01	8.10	2.28	6.31	3.58	9.11	3.71
8. Horizontal visibility in nest area (m)	54.28	28.54	27.04	14.06	14.43	8.33	32.80	24.17
9. Nest visibility (m)	46.57	18.66	18.13	13.76	10.04	6.26	25.21	20.45
10. Total base tree diameter/acre (m^2)	3.40	1.46	6.98	3.11	7.12	2.51	5.91	3.05
12. Ground cover in nest area (%)	53.80	32.57	25.77	24.16	18.53	14.44	32.90	29.02
13. Nest visibility (%)	36.20	16.41	14.62	10.66	12.65	12.76	20.86	16.56
14. Tree canopy in nest area (%)	63.32	14.19	84.10	10.90	81.76	85.41	78.74	13.46
15. Slope at nest site (%)	28.88	20.63	28.69	17.22	39.24	19.22	30.96	19.00
Sample size:	N = 25		N = 39		N = 17		N = 81	

4. Goshawks typically nest further from human disturbance than either sharp-shinned or Cooper's hawks.

5. Goshawks nest in larger trees and typically locate in larger stands of timber (average diameter of trees in the nest area is greater for goshawks and their nests are usually 4-6 m higher than those of the other hawks).

6. Sharp-shinned hawks appear to nest in heavier cover as is indicated by horizontal visibility (variable 8).

7. Conversely, goshawks typically nest in more sparsely timbered areas (variables 9, 12, 13).

8. The slope of the ground at the tree nest is very similar for all three species.

In the analysis of the standard deviation, variables 6 and 7 suggest that the individual species typically choose a certain age or type forest, since the means are separated and each have a rather small standard deviation. This also demonstrates the narrow requirements of the goshawk for nest height.

A word of caution might be inserted upon the evaluation of variables 2, 3, 5, 13, and 16 and to a lesser extent variables 4, 9, 10, 11, and 14. These standard deviations are quite large compared to their respective means. This might shed doubt on the results, since they are based on the variables collectively. The problem would probably correct itself if many more observations were available. Nevertheless, the data show definite tendencies which typify habitat requirements and aversion to human disturbance for each of the three hawk species.

Discriminant Function Analysis

Discriminant analysis is a procedure for estimating the position of an individual on a line that best separates classes or groups (Cooley and Lohnes, 1962). In this case, the analysis was used to determine the dispersion of variables (habitat parameters) for the three hawk species.

The analysis was made by a Multivariate Analysis system in a Completely Randomized Design (MACRD) program (Hurst, 1972). This program covers four related tests of the variables.

1. Test of variance (equality of dispersion).

   H_0: $\Sigma_1 = \Sigma_2 = \Sigma_3$

   $m = 1.590$

   $x^2_{.95(240)} = 276.85$

Since the calculated chi square (m) is less than the tabular value (x^2), the null hypothesis (H_0), that the data of the three groups (species) is equally dispersed, is accepted. By accepting this hypothesis, it can be concluded that the three accipiterine species have some dispersion (variance, covariance matrix) in the 15 quantitative variables.

2. Test of mean vector for the three groups (equality of means).

   H_0: $M_1 = M_2 = M_3$

   where: M_1, M_2, M_3 = mean vectors or array averages for the three respective groups.

The F approximation was then determined by the following (Cooley and Lohnes, 1962):

$$F = \left(\frac{1 - \Lambda}{\Lambda}\right)\left(\frac{N - g}{g - 1}\right) = 6.50$$

where: F = F approximation,

$\Lambda = |W| / |T|$, or the ratio of the pooled within-groups deviation score cross-products matrix to the total sample deviation cross-products matrix,

N = total number of measurements in a group, and

g = number of groups.

$F_{.95(30,128)} = 1.62$

Since the calculated F approximation (6.50) is greater than the tabular F (1.62), the null hypothesis is rejected. The conclusion is that there is a significant difference between the mean vector of the three groups, and so, the habitat parameters of the three hawks species are, in fact, unique.

3. Selection of variables.

To select variables with the most significant difference among the three groups (species), a univariate analysis of variance was made for each of the 15 variables with the groups (Table 4). The remaining 7 variables listed in Table 2 are qualitative and were not used in this test. Using the critical $F_{.95(2,78)} = 3.12$, a total of 9 variables were found with significant differences between groups (variables 3, 6, 7, 8, 9, 10, 12, 13, 14). The most significant or largest difference was associated with the largest F ratio (nest visibility, F = 41.66; nest height above ground, F = 30.11; and average tree diameter in nest area, F = 29.62). These ratios indicate distinct separation by the three hawk species in selection of these three habitat features.

The least significant differences in this test are for the variables with the smallest F ratios; nest distance to cover edge (F = 1.72) and the number of young fledged (F = 1.99).

Table 4. Univariate analysis of the 15 variables (habitat parameters) for three species of hawks.

No.	Variables	F Ratio
1.	Percent ground cover in nest areas	1.72
2.	Nest distance to water edge	2.56
3.	Elevation at nest site	14.90*
4.	Nest site to human disturbance	2.13
5.	Nest tree diameter	5.03
6.	Average tree diameter in nest area	29.62*
7.	Nest height above ground	30.11*
8.	Horizontal visibility in nest area	25.66*
9.	Nest visibility	41.66*
10.	Total basal tree diameter/acre	17.62*
11.	Number of young fledged	1.99
12.	Percent ground cover in nest areas	12.56*
13.	Percent nest visible	27.91*
14.	Percent tree canopy in nest area	14.81*
15.	Percent slope at nest site	2.10

* Indicates significant difference at 0.05 level

4. Stepwise deletion of variables.

A Stepwise Discriminant Function (SDF) test was run on the 15 quantitative variables (Hurst, 1972). This process deleted first the variables with the greatest discriminating power (Table 5). In other words, a trace of the matrix revealed that the variables, as listed in Table 5, exhibit the greatest to the least differences among them. Nest visibility, thus, differs the most as a haibtat parameter among the three hawk species. This finding is supported by the previous univariate analysis.

Orthogonal Discriminant Function Analysis

Discriminant analysis is a procedure for estimating the position of an individual on a line that best separates classes or groups (Cooley and Lohnes, 1962). An orthogonal function has the advantage of having uncorrelated discriminant scores. Thus, the transformed variables produced are uncorrelated and ordered in importance. Orthogonality is desirable in an analysis of the habitat parameters (variables) of the three hawk species since it permits independent examination of each variable. Nonorthogonal analysis contains correlated variables that are difficult to segregate in determining independent discrimination strengths.

Cooley and Lohnes (1962) give the Orthogonal Discriminant Function (ODF) as the solution of:

$$W^{-1}AV_i = \lambda_i V_i$$

where: λ = root of $|W^{-1}A - \lambda_i I| = 0$,

V_i = the columns of the weighting coefficients matrix, V,

W = error variance-covariance matrix, and

A = group variance-covariance matrix.

Table 5. Stepwise deletion of variables in descending order of differences among variables.

SDF deletion rank	Variable
1 (a)	nest visibility
2	nest height above ground
3	percent of nest visible
4	horizontal visibility in nest area
5	percent ground cover in nest area
6	percent slope at nest site
7	nest distance to water
8	nest distance to cover edge
9	elevation at nest site
10	nest tree diameter
11	number of young fledged
12	nest site to human disturbance
13	total basal tree diameter per acre
14	average tree diameter in nest site
15 (b)	percent tree canopy in nest area

(a) Item contributed least to α trace
(b) Item contributed most to α trace

The predicted values of this model are 91.6 percent reliable, which is very high in contrast to the second transformed variables with a reliability of 8.4 percent (Table 6).

The variance and covariance matrix for discriminant scores indicates the transformed variables are uncorrelated (Table 7).

The centroid matrix (Table 8) best shows the independence and overlap of each of the group variables.

This centroid matrix shows a 12 percent overlap between the habitat parameter for Cooper's hawks and sharp-shinned hawks, and a 0.2 percent overlap between goshawks and Cooper's hawks. The absence of overlap between goshawks and sharp-shinned hawks should also be noted.

This matrix demonstrates that the habitat parameters for Cooper's hawks and sharp-shinned hawks are highly nonhomogeneous while those of goshawks alone are homogeneous.

Principle Component Factor Analysis

Factor analyses include a variety of procedures developed for the purpose of analyzing the intercorrelations within a set of variables. One of these factor analyses, the principle components analysis, is a generally useful procedure whenever the task is to determine the minimum number of independent dimensions needed to account for most of the variance in the original set of variables (Cooley and Lohnes, 1962).

A total of 14 of the set of 23 variables (habitat parameter) were used for this analysis. These were based on 25, 39, and 17 observations for each variable for goshawks, Cooper's hawk, and sharp-shinned hawks, respectively.

Table 6. Orthogonal discriminant function (ODF) coefficients for variable analyzed in the accipiter hawk study.

Original variables	Transformed variables T_1	T_2
1	.0006	.02
2	.0007	.003
3	-.002	.001
4	.001	-.0005
5	.19	.22
6	.08	-.456
7	-.37	-.14
8	-.03	-.027
9	-.06	-.01
10	-.01	-.05
11	-.83	.78
12	-.03	.01
13	-.26	-.001
14	-.22	-.32
15	.04	.09
Root	145.93	13.34
Trace percent	91.6	8.4

Table 7. Variance and covariance matrix for 15 variables of three hawk species

	Group 1 goshawk	Group 2 Cooper's	Group 3 sharp-shinned
1	1.00	20.94	$.8 \times 10^{-7}$
2		$.8 \times 10^{-7}$	31.28
3			1.00

Table 8. The centroid matrix for 15 variables of three hawk species

	Group 1 goshawk	Group 2 Cooper's	Group 3 sharp-shinned
1	1.00	.002	0.00
2		1.00	0.12
3			1.00

A computer Factor Analysis (FACTA) was made for each species in an effort to determine the interrelationships between sets of independent variables and sets of dependent variables (Hurst, 1972). This analysis was conducted in order to analyze the ability of the independent variables to charcterize the population. The basis of the principle components is to form linear combinations of the independent variables to derive new dependent variables. Principle components were extracted for each of the three hawk species and also for a pooling of the three.

Through use of the principle components, an attempt was made to denote some population trait through the medium of a linear combination of the independent variables studied for the hawks under consideration (Tables 9-16). Subsequently, a factor characterizing the instinctive components of the population might reveal itself.

Generally, the hawks preferred a certain type stand of timber or area in which to nest. This seemed to be species specific and could be due to instinct. This "instinct" factor seemed to be closely allied to factor I in the pooled correlation matrix (Table 16), high positive loadings on elevation, average tree diameter in nest area, nest height above ground, horizontal visibility, nest visibility, and percentage nest visible. Sharp-shinned hawks seemed to display this characteristic (factor I) with high loadings on elevation, nest site to human disturbance, average tree diameter, and nest height (Table 14). Cooper's hawks followed suit with factor I typifying an instinctive sort of selection behavior. Specifically, the principle components analysis showed that the Cooper's hawk selected strongly for the habitat parameters and less so for elevation and percentage visibility (Table 12).

The goshawks, on the other hand, seemed to pick up this trend on factor II with good loadings on nest height above ground and percentage tree canopy. (A close examination of factor I for goshawks reveals that factor I probably more consistently depicts these instinctive trends but with negative loadings. This may or may not destroy the possibility that factor I is a better indicator of instinctive behavior than factor II for goshawks.)

A second factor which seemed to manifest itself was food and water availability. The aspect of water is obviously considered in the data

Table 9. Goshawk correlation matrix for various ecological parameters.

Variable	Variable 1	2	3	4	5	6	7	8	9	10	11	12	13	14
2. Nest distance to cover edge	1	-.29	-.16	.10	-.14	-.09	.06	-.19	.01	.19	.14	-.26	.25	.29
3. Nest distance to water		1	.19	.49	.14	.61	.30	.31	.29	-.54	-.17	.04	.05	-.06
4. Elevation at nest site			1	.34	.45	.46	.11	.28	-.08	-.37	-.22	-.11	-.49	-.30
5. Nest site to human disturbance				1	.17	.35	.30	.01	.24	-.34	-.22	-.01	.01	.16
6. Nest tree diameter					1	.48	.16	.06	.12	-.41	-.32	-.10	-.17	-.26
7. Average tree diameter in nest area						1	.52	.39	.38	-.75	-.01	-.23	-.08	-.32
8. Nest height above ground							1	-.14	-.06	-.12	-.11	-.17	.23	-.11
9. Horizontal visibility in nest area								1	.58	-.71	.34	-.04	-.44	-.07
10. Nest visibility									1	-.66	.21	.05	-.37	-.14
11. Total basal tree diameter/acre										1	-.11	.01	.36	.13
13. Percent ground cover in nest area											1	-.23	.05	.23
14. Percent nest visible												1	-.43	-.18
15. Percent tree canopy in nest area													1	.49
16. Percent slope at nest site														1

Note: N = 25

Table 10. Principal components analysis of the goshawk correlation matrix.

Variable	Vectors (factors)				
	I	II	III	IV	V
2. Nest distance to cover edge	.296	.338	.330	.219	.547
3. Nest distance to water	-.643	.325	.038	-.486	-.233
4. Elevation at nest site	-.592	.013	-.392	.375	.328
5. Nest site to human disturbance	-.446	.474	-.036	-.415	.495
6. Nest tree diameter	-.524	.160	-.377	.354	.128
7. Average tree diameter in nest area	-.838	.369	.050	.159	-.195
8. Nest height above ground	-.270	.661	-.146	.010	-.297
9. Horizontal visibility in nest area	-.638	-.381	.498	.081	-.036
10. Nest visibility	-.588	-.252	.497	-.180	.092
11. Total basal tree diameter/acre	.892	.048	-.300	.035	-.030
13. Percent ground cover in nest area	.085	-.164	.772	.252	-.164
14. Percent nest visible	-.013	-.518	-.338	-.619	.068
15. Percent tree canopy in nest area	.476	.720	.212	-.082	-.262
16. Percent slope at nest site	.387	.334	.490	-.249	.320
Latent roots	4.035	2.180	2.011	1.303	1.062
Variance (percent)	28.82	15.57	14.37	9.30	7.58
Cumulative variance (percent)	28.82	44.39	58.76	68.06	75.69

Table 11. Cooper's hawk correlation matrix for various ecological parameters.

Variable	Variable													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2. Nest distance to cover edge	1	-.07	.13	.25	-.03	.07	.08	.09	-.03	-.05	0	-.06	.08	-.01
3. Nest distance to water		1	.88	-.14	.03	.16	.28	.21	.08	.12	.21	.01	-.03	.07
4. Elevation at nest site			1	.43	.26	.56	.28	.07	.46	-.38	.08	.48	-.46	.13
5. Nest site to human disturbance				1	-.06	.53	.33	-.09	.06	-.29	-.07	.34	-.33	.29
6. Nest tree diameter					1	.21	.28	.24	0	-.31	.38	.38	-.18	.30
7. Average tree diameter in nest area						1	.71	.02	.44	-.77	.35	.49	-.60	.46
8. Nest height above ground							1	.12	.02	-.53	.48	.28	-.45	.38
9. Horizontal visibility in nest area								1	.08	.11	.34	.12	-.15	-.11
10. Nest visibility									1	-.37	.29	.13	-.36	.20
11. Total basal tree diameter/acre										1	-.29	-.48	.54	-.38
13. Percent ground cover in nest area											1	.09	-.34	.18
14. Percent nest visible												1	.70	.16
15. Percent tree canopy in nest area													1	-.34
16. Percent slope at nest site														1

Note: N = 39

Table 12. Principal components analysis of the Cooper's hawk correlation matrix.

Variable	Vectors (factors) I	II	III	IV	V
2. Nest distance to cover edge	.069	.186	.297	.705	.190
3. Nest distance to water	.184	-.527	.526	.077	-.300
4. Elevation at nest site	.672	.056	.569	-.132	.107
5. Nest site to human disturbance	.500	.576	.188	.319	.138
6. Nest tree diameter	.423	-.408	-.396	.026	.354
7. Average tree diameter in nest area	.904	.144	.087	.073	-.190
8. Nest height above ground	.710	-.162	-.167	.423	-.173
9. Horizontal visibility in nest area	.138	-.654	.198	.145	.407
10. Nest visibility	.463	-.241	.335	-.442	-.345
11. Total basal tree diameter/acre	-.778	-.225	.267	.024	.088
13. Percent ground cover in nest area	.471	-.619	-.207	.136	-.190
14. Percent nest visible	.667	.099	-.031	-.288	.548
15. Percent tree canopy	-.778	-.039	.029	.269	-.176
16. Percent slope at nest site	.518	.118	-.335	.134	-.375
Latent Roots	4.620	1.740	1.290	1.220	1.15
Variance (percent)	33.00	12.43	9.21	8.71	8.21
Cumulative variance (percent)	33.00	45.43	54.64	63.35	71.56

Table 13. Sharp-shinned hawk correlation matrix for various ecological parameters.

Variable	Varible													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2. Nest distance to cover edge	1	.01	.34	.41	-.01	.29	.30	.19	.63	-.18	-.14	-.29	.04	-.32
3. Nest distance to water		1	-.47	-.23	-.38	-.04	-.27	.10	-.10	.05	-.23	-.25	.55	-.20
4. Elevation at nest site			1	.60	.51	.52	.71	-.06	.09	.19	-.27	-.28	-.58	-.12
5. Nest site to human disturbance				1	.43	.74	.69	-.14	.10	-.16	-.32	-.30	-.44	-.05
6. Nest tree diameter					1	.11	.40	-.41	-.23	.63	-.03	.25	-.38	.44
7. Average tree diameter in nest area						1	.78	.25	.16	-.31	-.41	-.31	-.57	-.15
8. Nest height above ground							1	.16	.11	0	-.54	-.43	-.43	-.14
9. Horizontal visibility in nest area								1	.46	-.24	-.33	-.04	-.08	-.16
10. Nest visibility									1	-.12	-.15	-.24	.18	-.04
11. Total basal tree diameter/acre										1	.01	.23	-.03	.50
13. Percent ground cover in nest area											1	.49	-.08	.34
14. Percent nest visible												1	-.32	.51
15. Percent tree canopy in nest area													1	-.34
16. Percent slope at nest site														1

Note: N = 17

Table 14. Principal components analysis of sharp-shinned hawk correlation matrix.

Variable	Vectors (factors)				
	I	II	III	IV	V
2. Nest distance to cover edge	.486	.386	.112	.466	.492
3. Nest distance to water	-.307	.592	-.405	.122	-.297
4. Elevation at nest site	.822	-.279	-.095	.054	.146
5. Nest site to human disturbance	.841	-.115	-.059	-.101	.186
6. Nest tree diameter	.366	-.768	-.347	.216	.047
7. Average tree diameter in nest area	.845	.109	.188	-.183	-.230
8. Nest height above ground	.913	-.037	-.124	-.036	-.166
9. Horizontal visibility in nest area	.151	.477	.502	.292	-.538
10. Nest visibility	.234	.479	.261	.719	.152
11. Total basal tree diameter/acre	-.114	-.568	-.525	.529	-.212
13. Percent ground cover in nest area	-.511	-.384	.397	-.022	.481
14. Percent nest visible	-.423	-.584	.449	.125	-.118
15. Percent tree canopy	-.533	.578	-.481	.147	.196
16. Percent slope at nest area	-.193	-.694	.143	.378	-.225
Latent Roots	4.247	3.24	1.546	1.384	1.16
Variance (percent)	30.34	23.14	11.05	9.89	8.29
Cumulative variance (percent)	30.34	53.48	64.53	74.42	82.71

Table 15. Pooled accipiter hawk correlation matrix for various ecological parameters.

Variable	Variable 1	2	3	4	5	6	7	8	9	10	11	12	13	14
2. Nest distance to cover edge	1	-.06	.16	.25	-.02	.14	.18	.02	.14	-.10	.11	-.06	.03	.06
3. Nest distance to water		1	.11	.05	-.01	.22	.10	.18	.15	-.06	-.03	.03	.02	-.01
4. Elevation at nest site			1	.48	.45	.68	.56	.40	.48	-.45	.19	.38	-.62	-.09
5. Nest site to human disturbance				1	.20	.52	.45	.10	.25	-.33	-.03	.18	-.29	.14
6. Nest tree diameter					1	.37	.35	.20	.20	-.23	.12	.26	-.31	.08
7. Average tree diameter in nest area						1	.80	.53	.67	-.77	.40	.44	-.59	-.01
8. Nest height above ground							1	.41	.47	-.52	.36	.35	-.42	-.04
9. Horizontal visibility in nest area								1	.66	-.44	.51	.39	-.50	-.15
10. Nest visibility									1	-.60	.49	.47	-.55	-.07
11. Total basal tree diameter/acre										1	-.40	-.46	.55	-.02
13. Percent ground cover in nest area											1	.29	-.34	.13
14. Percent nest visible												1	-.66	.01
15. Percent canopy in nest area													1	.03
16. Percent slope at nest site														1

Note: N = 81

Table 16. Principal components analysis of accipiter hawk pooled correlation matrix.

Variable	Vectors (factors) I	II	III	IV	V
2. Nest distance to cover edge	.156	.470	.604	.054	.388
3. Nest distance to water	.154	-.104	.248	-.564	-.706
4. Elevation at nest site	.757	.268	-.222	-.179	.058
5. Nest site to human disturbance	.487	.678	-.072	-.089	-.038
6. Nest tree diameter	.447	.229	-.456	.131	-.163
7. Average tree diameter in nest area	.908	.149	.269	-.128	-.081
8. Nest height above ground	.759	.235	.082	-.114	.020
9. Horizontal visibility in nest area	.683	-.440	.164	-.108	.031
10. Nest visibility	.788	-.250	.207	-.025	.061
11. Total basal tree diameter/acre	-.776	.028	-.085	-.085	-.017
13. Percent ground cover in nest area	.528	-.398	.424	.369	-.024
14. Percent nest visible	.635	-.241	-.321	.221	-.005
15. Percent tree canopy	-.765	.152	.315	-.142	-.098
16. Percent slope at nest site	-.213	.298	.169	.707	-.565
Latent roots	5.42	1.478	1.183	1.133	1.021
Variance (percent)	38.69	10.56	8.45	8.09	7.29
Cumulative variance (percent)	38.69	49.25	57.70	65.79	73.08

explicitly whereas food is concealed in the variables 2 and 13, i.e., nest distance to cover edge and percentage ground cover. In this case, since the majority of the diet of the birds can be found in the ground cover (small birds, rabbits, and rodents), the pooled case suggests either factor IV or V. Factor IV would probably be more correct as the percentage ground cover is a better indicator of available food than nest distance to edge of cover.

For sharp-shinned hawks, factor V definitely suggests this trend with good positive loadings on ground cover variables and a negative loading (minimize distance) for the water criterion.

Cooper's hawk analysis was less pronounced, but IV and V seem appropriate with IV probably being a little better.

Factor IV for goshawks looked better on the food and water criterion, and although factor V was similar, it does not explain the characters as well.

The three species of hawks have marked differences in their nesting site preferences but could possibly be similar in some sense since they follow instinctive impulses and apparently seek to maximize their food and water availability.

Canonical Correlation Analysis

Canonical correlation methods are similar to multiple regression analyses but are used to study the interrelations between two sets of measurements made on the same subjects. For example, tree diameter in a nest area will reveal much about nest tree diameter, nest height, and nest visibility. These relationships can be determined from a series of vectors which relate chosen dependent and independent variables.

In the following analysis, an attempt was made to seek out high positive or negative loading on both dependent and independent variables, or inverse relationships which indicate appropriate correlations. Three sets of comparisons were made to reveal some of the many combinations possible from the data collected on the three hawks (Tables 17-19). The three sets were analyzed independently but reveal common vector characteristics.

The canonical R^2 (a measure of the correlation between dependent and independent variables) and percentage trace (a measure of the variance within a particular set) were determined for these nest data (Tables 17-19).

Each vector is a predictor for a particular habitat characteristic. That characteristic is revealed by the apparent relationships indicated from the cannonical correlation analyses.

Some examples of what may be gleamed from this analysis are presented. This technique, as well as the principle components analysis, is subject to a high degree of interpretation. Conclusions are subject to the analyst's intuition, perception, and knowledge of the subject matter. Other interpretations are not only possible, but highly probable.

Goshawks: set A, vector 1

The high negative loading on average tree diameter (independent variable) and correspondingly high negative loading on nest tree diameter and nest height (dependent variables) suggest that the latter two can be predicted by the former (Table 17). The canonical R^2 of 0.442 at the 0.05 level supports this observation.

Table 17. Canonical correlation analysis for accipiter hawk data. (set A).

Variables	Canonical vectors								
	Goshawk			Cooper's hawk			Sharp-shinned hawk		
	1	2	3	1	2	3	1	2	3
Independent variables									
4. Elevation at nest site	-.148	.680	.640	.562	.215	.692	-.659	.572	.547
7. Average tree diameter in nest area	-.984	-.584	-.475	.202	-.976	-.528	.396	-.646	.827
10. Percentage slope at nest site	.102	-.443	.767	-.802	-.042	.492	-.690	-.505	-.130
Dependent variables									
2. Nest distance to cover edge	.161	-.517	.764	.972	.022	.252	.057	.869	.143
6. Nest tree diameter	-.700	.518	.538	-.234	.243	.936	-.964	.205	-.010
8. Nest height above ground	-.696	-.681	-.356	-.005	-.998	-.245	.258	-.450	.985
Canonical R^2	.442	.130	.037	.011	.518	.109	.509	.062	.753
Trace percent	72.5	21.3	6.2	1.7	81.1	17.2	38.4	4.8	56.8
Sample size		N = 25			N = 39			N = 17	

Table 18. Canonical correlation analysis for accipiter hawk data. (set B).

Variables	Canonical vectors								
	Goshawk			Cooper's hawk			Sharp-shinned hawk		
	1	2	3	1	2	3	1	2	3
Independent variables									
4. Elevation at nest site	.514	.686	--	-.775	.626	--	.703	-.435	--
7. Average tree diameter in nest area	-.883	.312	--	.584	.764	--	-.536	.893	--
16. Percentage slope at nest site	.095	.657	--	.242	.155	--	.468	.118	--
Dependent variables									
5. Nest site to human disturbance	-.067	.958	--	.677	.739	--	.189	.995	--
10. Nest visibility	-.998	-.286	--	-.736	.672	--	-.982	.095	--
Canonical R^2	.237	.272	--	.010	.536	--	.003	.662	--
Trace percent	46.6	53.4	--	1.8	98.2	--	.4	79.6	--
Sample size		N = 25			N = 39			N = 17	

Table 19. Canonical correlation analysis for accipiter hawk data. (set C).

Variables	Canonical vectors: Goshawk 1	2	3	Cooper's hawk 1	2	3	Sharp-shinned hawk 1	2	3
Independent variables									
7. Average tree diameter in nest area	.447	.410	.440	-.295	-.327	.810	.711	.131	-.003
9. Horizontal visibility in nest area	-.695	-.067	.635	-.686	-.245	-.335	.233	-.811	-.035
11. Total basal tree diameter/acre	-.420	.892	.386	.043	.256	.159	.234	-.051	-.628
15. Percentage tree canopy in nest area	.182	.090	.483	-.587	.866	.454	.628	.012	.574
16. Percentage slope at nest site	-.328	.150	.141	-.310	.128	.012	-.126	-.568	.542
Dependent variables									
10. Nest visibility	.276	-.973	.194	-.006	-.346	.875	.466	-.603	.477
13. Percentage ground cover	-.838	-.015	.374	-.856	-.380	-.372	-.720	.291	.750
14. Percentage nest visible	-.470	-.231	-.907	.516	-.858	-.308	-.514	-.742	-.458
Canonical R^2	.150	.504	.325	.101	.688	.041	.636	.353	.022
Trace percent	15.3	51.5	33.2	12.2	82.9	4.9	57.2	31.7	11.1
Sample size		N = 25			N = 39			N = 17	

Goshawks: set B, vector 1

Here, average tree diameter might be a fairly good predictor of nest visibility (Table 18). This seems consistent with the previous set since higher nests tend to coincide with larger trees. The larger trees are also more sparse and allow greater nest visibility. However, this vector has an R^2 of only 0.237 and is probably not a good predictor.

Goshawks: set C, vector 2

In this vector, high positive loading occurs on total basal tree diameter/acre and high negative loading on nest visibility (Table 19). This vector seems to relate larger trees and dense stands to reduced nest visibility. This predictor seems reasonable but has a low R^2 of 0.504.

Cooper's hawk: set A, vector 2

The high negative loading on average tree diameter in the nest area and nest height above ground (Table 17) reveals a correlation between tree size and nest height much as did vector 1 of the same set for goshawks. The vector exhibits a moderate R^2 of 0.518.

Cooper's hawk: set B, vector 2

There is moderate to high positive loading in nest site elevation, average tree diameter in nest area, and nest site to human disturbance, nest visibility (Table 18). This vector appears to predict human disturbance and nest visibility from the former two independent variables (R^2 = 0.536).

Cooper's hawk: set C, vector 2

High positive loading on percentage tree canopy and corresponding negative loading on percentage nest visibility (Table 19) indicate that this vector predicts reduced nest visibility from increased tree canopy (R^2 = 0.688).

Sharp-shinned hawk: set A, vector 3

For the sharp-shinned hawk, there appears to be a high correlation (R^2 = 0.753) between average tree diameter in nest area and nest height above ground (Table 17). This characteristic relationship appears in vectors derived for the other species, but at lower levels of correlation.

Sharp-shinned hawk: set B, vector 2

This vector seems to predict nest site distance to human disturbance from average tree diameter (Table 18). Although the correlation (R^2 = 0.662) is moderately high, the relationship is intuitively not very plausible.

Sharp-shinned hawk: set C, vector 1

High positive loading on average tree diameter in nest area and percentage tree canopy and negative loading on percentage ground cover and nest visibility (Table 19) indicate that like other vectors, this one predicts a negative correlation (R^2 = 0.636) between tree size, and ground cover and nest visibility.

Multiple Regression Analysis

In this analysis, all variables relating to the number of young fledged (for all three species) were ranked according to importance (Figure 2). The first six variables have the greatest impact on the number of young fledged, as indicated by the slope of the line. Of the 22 variables examined, these six account for about 40 percent of the variation.

By using the multiple regression model, the increase or decrease in number of young produced was predicted (Table 20). These predictions reveal that increases in nest height and tree canopy can be detrimental to fledgling production. Little change is seen from increases in the other variables, although the unit of increase does not remain constant.

The analysis of the number of accipiter young produced per nest based on the total multiple regression model is presented in Table 21. This information indicates that the goshawk is an important variable in production of young; the difference in young produced between the bottom (0.4) and top of the slope (0.1) is substantial. Also, a well developed tree canopy can mean a difference of 1.3 young over an area absent of canopy. Slope aspect is an equally important variable. The model predicts a difference of 1.4 young between an east aspect (0.7) and no slope (-0.7).

Assuming equal numbers of hawks in each category, it is possible from this regression model to predict the number of fledglings per nest for each species. It was predicted that goshawks fledged 2.5 young per nest; Cooper's hawks, 1.1; and sharp-shinned hawks, 1.1. The predicted pooled average for all three accipiter species was 1.6 fledglings per nest.

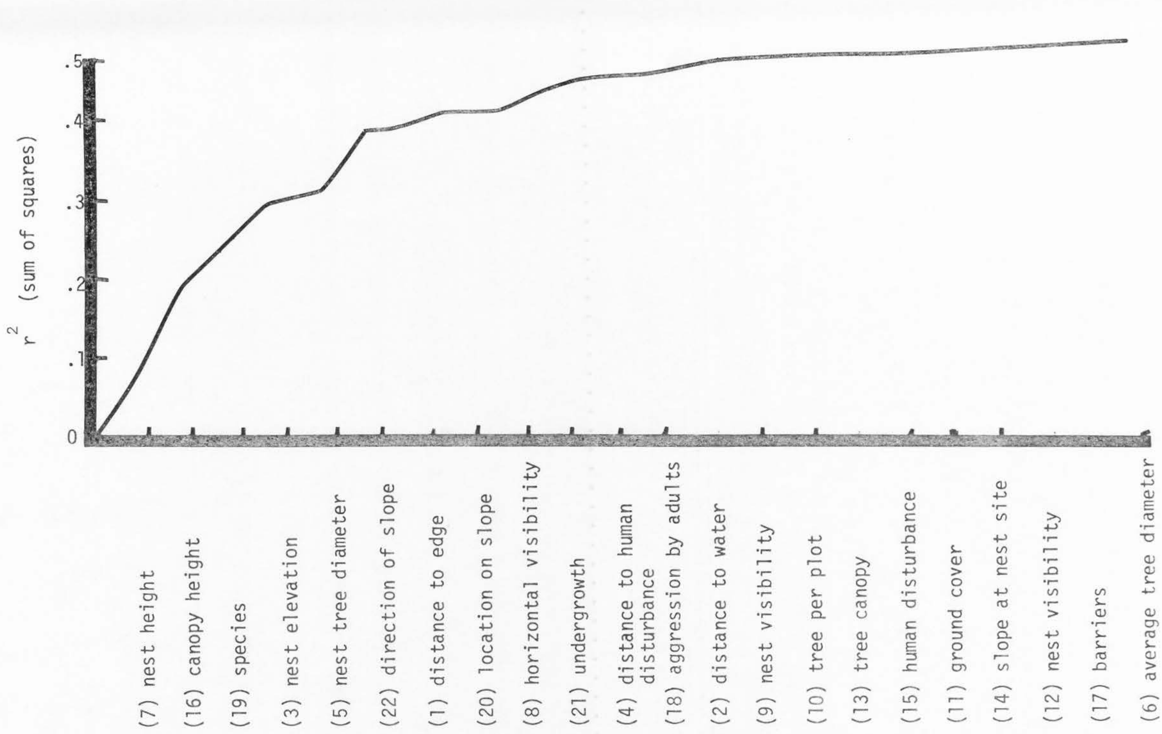

Figure 2. Graph of r^2 values from multiple regression ranked according to their importance in relation to the number of young fledged for three hawk species.

Table 20. Predicted changes in number of accipiter young fledged in relation to increase in unit, taken from multiple regression coefficients using all data.

Unit of increase (meters)	Variable	Absolute increase in number of fledglings
0.6	distance to edge	<.01
1.2	elevation increase	<.01
0.2	nest tree diameter	.06
2.4	nest height above ground	-.06
2.7	horizontal visibility in nest area	<.01
5.5	nest location in canopy	-1.84

Table 21. The number of accipiter young fledged per nest based on total multiple regression model.

Variable	Number of young fledged
Goshawk	0.9*
Cooper's hawk	-0.5*
Sharp-shinned hawk	-0.4*
Top of slope	<0.1
Middle of slope	-0.4
Bottom of slope	0.4
Canopy absent	-0.6
Canopy slight	-0.2
Canopy moderate	0.2
Canopy well developed	0.6
North slope	0.4
East slope	0.7
South slope	-0.2
West slope	-0.1
Flat (no slope)	-0.7

*compared to other two species

RESULTS AND DISCUSSION

Description of Nest Sites

A total of 94 active accipiter nests (42 Cooper's, 20 sharp-sinned, 32 goshawk) were located during the 1973 and 1974 nesting seasons. Two of the goshawk nests were destroyed by logging and so, no data were collected on nest woods composition. The characteristics of the remaining sites are analyzed in Tables 22-28.

Although not dramatically demonstrated by the data, there was a tendency for all three species to locate their nests near or directly on trails, meadow edges, dirt roads, or similar clearings (Table 22). Jameson and Peeter (1970) also noted this in regard to Cooper's hawks in California. These clearings appear to provide clear flight lanes to and from the nest. They also appear to play a role in providing good hunting areas, since disturbance of vegetation often encourages growth of various grasses and shrubs attractive as food for small animals. The open areas make small prey more vulnerable. Accipiters are commonly seen "still hunting" along the edges of such areas. Regardless of the function of nesting near these openings, this habitat increases the probability of human activity around the nest site.

A feature common to all of the 94 nest sites was their proximity to water, i.e. stream, river, stock pond (Table 23). The maximum distance to water was about 1.6 km, and the majority of nests were within 1 km of some water. This relationship has often been observed by other workers (Beebe and Webster, 1964; Meng, 1951). It is possible that frequent

Table 22. Distance from accipiter hawk nest tree to nearest edge (dirt road, meadow, etc.) on the Cache National Forest, Utah-Idaho study area.

Accipiter species	Number (percentage) of nests in each distance category				
	Distance in meters				Total number of nests
	0-15	15-30	30-60	60+	
Goshawk	8 (30)	6 (22)	8 (30)	5 (18)	27
Cooper's hawk	18 (43)	11 (26)	9 (21)	4 (10)	42
Sharp-shinned hawk	12 (60)	0	1 (5)	7 (35)	20

Table 23. Distance from accipiter hawk nest tree to nearest water on the Cache National Forest, Utah-Idaho, study area.

Accipiter species	Number (percentage) of nests in each distance category				
	Distance in meters				Total number of nests
	0-15	15-30	30-60	60+	
Goshawk	1 (4)	6 (21)	8 (29)	13 (46)	28
Cooper's hawk	10 (24)	19 (45)	4 (10)	9 (21)	42
Sharp-shinned hawk	2 (10)	6 (30)	4 (20)	8 (40)	20

Table 24. Elevation of area at accipiter hawk nest tree on the Cache National Forest, Utah-Idaho, study area.

Accipiter species	Elevation in meters		
	Maximum	Minimum	Average
Goshawk	2469	1737	2103
Cooper's hawk	2225	1433	1853
Sharp-shinned hawk	2469	1554	1839

Table 25. Location of accipiter hawk nest tree on slope on Cache National Forest, Utah-Idaho, study area.

Accipiter species	Number on bottom third of slope	Number on middle third of slope (percentage)	Number on upper third of slope	Total number of nests
Goshawk	14 (50)	8 (29)	6 (21)	28
Cooper's hawk	33 (79)	6 (14)	3 (7)	42
Sharp-shinned hawk	16 (80)	3 (15)	1 (5)	20

Table 26. Exposure of accipiter hawk nest slope on the Cache National Forest, Utah-Idaho, study area.

Accipiter species	Number of nests by slope exposure				
	northern	eastern	southern	western	flat ground
Goshawk	14	4	2	6	2
Cooper's hawk	25	5	3	6	3
Sharp-shinned hawk	16	1	0	3	0

Table 27. Accipiter hawk nest tree species on the Cache National Forest, Utah-Idaho, study area.

Tree species	Hawk species		
	Goshawk	Cooper's hawk	Sharp-shinned hawk
Lodgepole pine (*Pinus contorta*)	3	1	0
Spruce (*Picea* sp.)	1	0	1
Fir (*Abies* sp.)	6	10	10
Aspen (*Populus tremuloides*)	17	5	0
Maple (*Acer* sp.)	0	26	4
Chokecherry (*Prunus virginiana*)	0	0	1
Cottonwood (*Populus* sp.)	1	0	0
Juniper (*Juniperus* sp.)	0	0	4
Total number of nests	28	42	20

Table 28. Nest tree composition on the accipiter hawk study area, Cache National Forest, Utah-Idaho.

Tree species	Hawk species		
	Goshawk	Cooper's hawk	Sharp-shinned hawk
Lodgepole pine (*Pinus contorta*)	2	0	0
Fir (*Abies* sp.)	3	2	3
Aspen (*Populus tremuloides*)	8	3	0
Maples (*Acer* sp.)	0	13	6
Spruce-fir (*Picea* - *Abies*)	0	0	1
Aspen-fir (*Populus* - *Abies*)	5	5	4
Chokecherry-maple (*Prunus* - *Acer*)	0	7	3
Fir-maple (*Abies* - *Acer*)	1	4	2
Maple-juniper (*Acer* - *Juniperus*)	0	1	1
Maple-aspen (*Acer* - *Populus*)	3	6	0
Lodgepole-aspen (*Pinus* - *Populus*)	0	1	0
Maple-cottonwood (*Acer* - *Populus*)	1	0	0
Aspen-spruce-fir (*Populus* - *Picea* - *Abies*)	1	0	0
Fir-lodgepole (*Abies* - *Pinus*)	2	0	0
Total number of nests	26	42	20

bathing by the female helps maintain proper humidity in the nest during incubation. Also, free water is a possible aid to thermoregulation by the birds.

Nest tree elevation was typically higher for goshawks (Table 24), although the maximum range of the sharp-shinned equalled that of the former.

Features common to the nests of all three species include a tendency to locate the nest on the lower third of the slope (Table 25) and a preference for northern exposures (Table 26).

The three hawk species did appear to select distinct nest sites within the Cache National Forest study area. Goshawks seemed to favor a mature forest with little undergrowth. Nests were frequently found in large aspen (Populus tremuloides) and were invariably built against the main trunk in a large fork. Nests of this species were also found in conifers, usually in a fairly uniform stand of mature trees (Table 27). There appeared to be a preference for areas that had been selectively logged 30-40 years before.

Areas favored by Cooper's and sharp-shinned hawks were similar in many respects. Nests were most often found in canyons containing thick growths of maple (Acer sp.) often interspersed with conifers along the lower parts of the adjacent slopes.

These accipiters often nested in trees which were, in some respect, different from the surrounding trees. Trees with abnormal growth form or with disease were selected as nest sites, as were trees of a species different from the predominant type in the nest woods. For instance, sharp-shinned hawks commonly placed their nests in lone conifers among groves of deciduous trees (Table 28). Platt (1973) also noted this and postulated that this was done to keep the nest below the canopy; such aberrant trees more often provide suitable nest support below the canopy than the predominant types. In the present study, this was more evident with sharp-shinned hawks than with either Cooper's hawks or goshawks.

Reproductive Timing

Most nests were visited several times during the breeding cycle and the stage of reproduction recorded. Figure 3 shows the ranges and median dates for observations of various reproductive activities for the 1973 and 1974 pooled data. No attempt was made to extrapolate these data; i.e. if a nest was visited on June 15 and estimated week-old downies were found, they were recorded as hatched on June 15 rather than on June 8. In general, the breeding cycles of the three species are slightly staggered, with the goshawks beginning earliest and the sharp-shinned hawks latest.

Response to Vocalization

Amplified vocalizations of all three species were used at different stages during the breeding season as an aid in locating new nest sites. The results were very inconsistent, probably because of the limitations of the electronic equipment. Much greater success was obtained using vocal imitations.

After the young had fledged, the food beg call was generally quite successful in attracting both immature birds and, to a lesser extent, adults. Adults with small downies in the nest were also occasionally located using this call, although earlier in the season it produced no response.

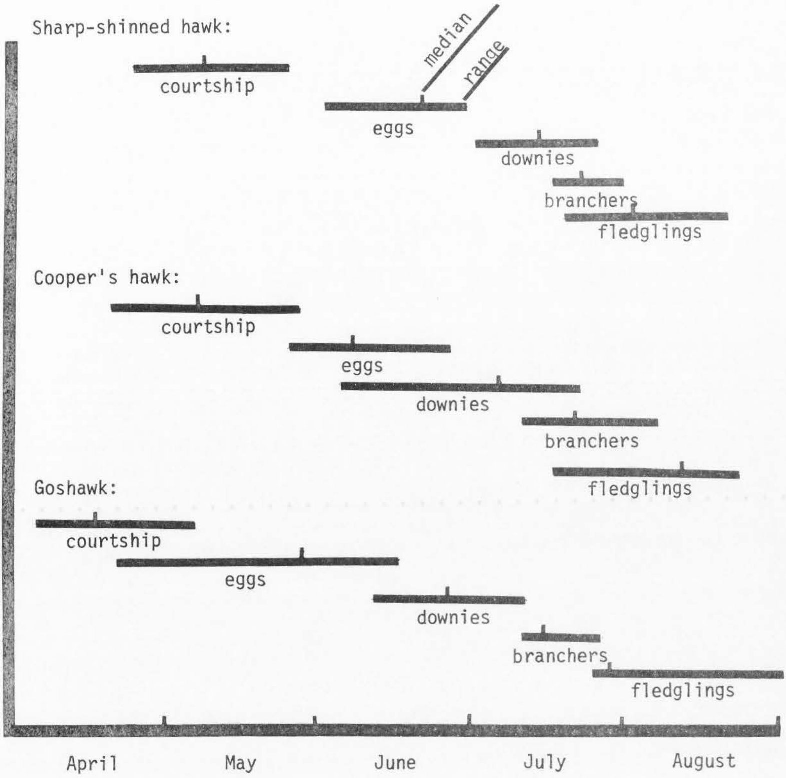

Figure 3. Mating and reproduction sequence in 1973-1974 for three species of hawks on the Cache National Forest, Utah-Idaho.

The nest defense call of the adult bird was less effective. Responses were elicited from adult birds of all three species; but these instances were rare and it was concluded that this call was not successful in locating new nests.

The use of electronically broadcast vocalizations is a potentially useful technique in locating accipiter nests. It is probably most useful during the last half of the nesting season when there are young in the nest.

Aggression of Adult Birds

The ultimate fate of accipiters nesting in proximity to human activity may, in part, depend on the degree to which each individual pair adjusts to that disturbance. Birds nesting in remote areas, such as goshawks in the boreal forests of Canada, generally react to human intrusion by attacking, sometimes as far as one-half mile from the nest (Beebe and Webster, 1964). Such behavior in populous areas would probably be detrimental to the success of the pair.

In this study, reactions of the various nesting pairs to human activities were noted. While pairs in high disturbance areas tended to be more tolerant, there were some notable exceptions. The distance from the nest at which the adult bird would attack or protest the presence of an intruder varied, as did the intensity of the protest. Several factors seemed to have an effect on this variation. The more vigorous protests occurred late in the breeding cycle (Figure 4). A large number of people would illicit a milder protest and less likelihood of an actual attack than fewer people.

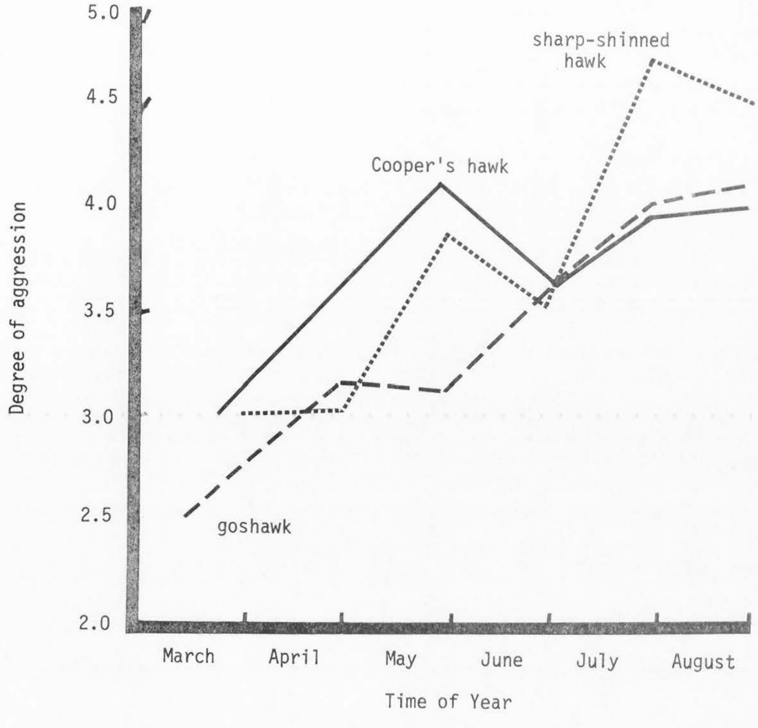

Figure 4. Aggression in accipiter hawks during the breeding seasons of 1973-1974 on the Cache National Forest, Utah-Idaho.

The age of the adult may also be important. Female Cooper's hawks breeding in immature plumage and female goshawks breeding in the first year adult plumage tended to be more vigorous in their attacks than the older, adult birds. Females were the most aggressive, while males were rarely seen at the nest site.

Nesting Success

Approximately 38 percent (36) of the 94 nests observed during the 2 years failed. Some of the causes of failure are presented in Table 29. Henny and Wight (1972) and Parratt (1959) indicate that some mortality of older nestlings can be attributed to starvation, cannibalism, or disease. Losses to predation by great horned owls (Bubo virginianus) or older nestlings or fledglings is also recognized, but not quantified. Craighead and Craighead (1956) found that the great horned owl preyed on several species of raptors, and killed adult hawks on the nest as well as nestlings. Reynolds[1] reports that in his study area in Oregon only 2-3 of the 20 nests would be expected to fail in any given year. Great horned owls and raccoons are the most significant predators.

Based on actual observation of the successful nests, the average number of young per nest was 1.4, 1.6, and 2.1 for goshawk, Cooper's hawk, and sharp-shinned hawks, respectively (Table 30). The maximum number of young (5) was found in a nest of sharp-shinned hawks.

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[1]Personal communication (letter) with Mr. R. T. Reynolds, research assistanc, Department of Fisheries and Wildlife, Oregon State University, Cowallis, Oregon. 1973.

Table 29. Causes of failure of accipiter hawk nests on the Cache National Forest, Utah-Idaho (1973-74).

Cause of failure	Accipiter species		
	Goshawk	Cooper's hawk	Sharp-shinned hawk
Human disturbance (roads, logging, campsites, etc.)	3	2	1
Great horned owls (owls seen near nest or feathers and other signs in evidence)	4	4	0
Other predators (bobcats, magpies, etc.)	2	4	2
Weather (freak spring snow storm in 1974 and wind)	1	4	2
Unknown causes	2	3	2
TOTAL	12	17	7

Table 30. Number of accipiter hawk young per nest on the Cache National Forest, Utah-Idaho, study area.

Accipiter species	Average for all nests	Average for successful nests	Maximum in any nest
Goshawk	1.4	2.1	3
Cooper's hawk	1.6	2.6	4
Sharp-shinned hawk	2.1	3.2	5

Other Findings

Breeding female Cooper's hawks are usually in full adult plumage (two or more years old). During the 1973 nesting season, 27 percent of the female Cooper's hawks nesting on the study area were immature (one year old). Snyder[1] found a similar situation in Arizona and New Mexico where 30 percent of the nesting female Cooper's hawks in 1973 were immature. In previous years, less than 2 percent of the females in her study area were immature. Evidently, either an unusually high mortality of adult females occurred during the winter of 1972-73, or the production of young in 1971 was far below normal. Since males are rarely seen at the nest site, it is uncertain whether any were one year olds.

Another unusual occurrence on the study area in 1973 was the large number of nesting long-eared owls (Asio otus). Fourteen active nests were found and several other occupied territories located. The nesting

[1]Personal communication (letter) with Ms. H. Snyder, field biologist, Department of Biology, University of New Mexico, Albuquerque. 1973.

habitat of the long-eared owl corresponds almost exactly with that of the Cooper's hawk. Of the 14 nests located, one was in an old magpie nest, one in an old goshawk nest, and the rest were in old Cooper's nests. While these owls reportedly prey mostly on small rodents, remains of small passerines were not uncommon around the nest sites. The degree of competition between Cooper's hawks and long-eared owls is not known; in one case in this study a pair of long-eared owls appeared to have displaced a pair of Cooper's hawks from their territory. In another case, a pair of Cooper's hawks and a pair of long eared owls nested successfully about 45 m apart; both pairs were fledging young. Approximately half of the long-eared owl nests were checked when the young were several weeks old, and all contained either three or four young.

Analysis of accipiter hawk eggs from the Cache National Forest study area revealed the presence of agricultural contaminants (Table 31). High levels of chlorinated hydrocarbons, particularly the DDT metabolite, DDE (dieldrin), were found in the eggs of goshawks, Cooper's hawks, and sharp-shinned hawks. The pathways for these insecticide residues are many, including prey from local agricultural valleys which still employ these insect controls. These agricultural contaminants are associated with reproductive failure (Cade, et al., 1971; Enderson and Berger, 1968; Walker, 1977).

One of the principle reasons for this failure appears to be the reduction in egg shell thickness. Shell thickness from eggs collected in accipiter hawk nests on this study was determined (Table 32). These data were limited by sample size and any interpretation is difficult because of the lack of species-specific information on these species.

SUMMARY

1. Cooper's hawks, sharp-shinned hawks and goshawks in the Cache National Forest preferred to nest in trees surrounded by a canopy of cover.

2. Nest distance to the edge of cover was important. The goshawk showed the greatest preference for more distance ($\overline{X}$ = 56 m), and the Cooper's hawk the least ($\overline{X}$ = 34 m).

3. Nests of sharp-shinned hawks were located farther from water ($\overline{X}$ = 444 m), than those of goshawks ($\overline{X}$ = 394 m), while nests of Cooper's hawks were usually closest ($\overline{X}$ = 220 m).

4. Nests of goshawks were usually found about 300 m higher in elevation ($\overline{X}$ = 2,065 m) than those of Cooper's or sharp-shinned hawks.

5. Nests of goshawks were typically farther from human disturbance ($\overline{X}$ = 250 m) than those of Cooper's ($\overline{X}$ = 147 m) and sharp-shinned hawks ($\overline{X}$ = 161 m).

6. Nesting was more successful for all three accipiters when the nest was at the bottom of a slope under a well-developed canopy.

7. Goshawks nested higher, required more horizontal visibility, and had greater nest visibility and ground cover (related to nest woods) than sharp-shinned or Cooper's hawks.

8. Sharp-shinned hawks utilized smaller nest trees and built nests closer to the ground than the other two species.

9. Distribution of Cooper's hawk nests slightly overlapped that of the goshawk, and broadly overlapped that of the sharp-shinned hawk.

However, nests of goshawks were found exclusive of those of sharp-shinned hawks.

10. The number of young fledged (all three species) was higher with greater distance between the nest and the edge of cover, greater tree diameter, and greater horizontal visibility.

11. The number of young fledged (all three species) was less in nests at higher elevation, those highest above ground, and those with greater height in canopy.

12. Although there was a greater number of accipiter nests on the north-facing slope than any other aspect, the fledging rate per nest was highest on east-facing slopes.

13. In the final analysis, goshawks fledged an average of 1.4 young per nest; Cooper's hawks, 1.6 young per nest; and sharp-shinned hawks, 2.1 young per nest on the Cache Forest study area.

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APPENDICES

Appendix A:

Analysis of Accipiter Hawk Egg Residues Conducted on Eggs Collected on the Cache National Forest, Utah-Idaho

Table 31. Analysis of accipiter hawk egg residues[1] conducted on eggs collected on the Cache National Forest, Utah-Idaho.

Sample number	Field number	Sample size (grams)	Lipid weight (grams)	DDE[2]	DDD[2]
17957	1	2.0	.08	0.46	
17958	2	2.0	.16	0.93	
17959	3	2.0	.12		
17960	3	2.0	.13	1.3	
17961	4	2.0	.14	1.5	
17962	5	2.0	.12	1.2	
17963	6	2.0	.08	2.6	
17964	7	2.0	.15	1.1	
17965	8	2.-	.19	1.1	
17966	9	2.0	.12	2.5	
17967	10	2.0	.14	2.8	
17968	11	2.0	.12	2.6	
17969					
17970	12	2.0	.09	1.1	
17971	13	2.0	.08	2.5	
17972	14	2.0	.11	1.0	
17973	15	2.0	.11	.93	
17974	16	2.0	.05	6.0	
17975	17	2.0	.10	3.8	
17976	18	sample lost in preparation			
17977	19	2.0	.12	3.0	
17978	20	2.0	.12	2.5	
17979	22	2.0	.12	5.0	
17980	22	2.0	.13	4.9	
17981	21	2.0	.56	67.0	1.0
17982	23	2.0	.08	2.5	
17983	24	2.0	.14	3.8	
17984	25	2.0	.11	4.2	

[1]Analysis of egg residues by the Denver Research Center.
[2]Parts per

Appendix B:

Shell Thickness from Eggs Collected in Accipiter Hawk Nests on the Cache National Forest, Utah-Idaho

Table 32. Shell thickness from eggs[1] collected in accipiter hawk nests on the Cache National Forest, Utah-Idaho.

Accipiter category	Measurement in millimeters	
	with membrane	without membrane
Sharp-shinned hawk[2]		
number	1	1
minimum measurement	.211	.289
maximum measurement	.211	.289
average measurement	.211	.289
Cooper's hawk[2]		
number	7	10
minimum measurement	.241	.187
maximum measurement	.281	.280
average measurement	.264	.229
Accipiters (general)[3]		
number		17
minimum measurement		.214
maximum measurement		.417
average measurement		.314

[1] All measurements were taken around the egg equator. Four to six measurements were taken for each egg.

[2] 1972-73 measurements were made by Helen Snyder, U.S. Fish and Wildlife Service.

[3] 1974 measurements were made by Steve Hennessy, Utah State University.

VITA

Stephen P. Hennessy

Candidate for the Degree of

Master of Science

Thesis: Ecological Relationships of Accipiters in Northern Utah - With Special Emphasis on the Effects on Human Disturbance.

Major Field: Wildlife Science

Bibliographical Information:

Personal Data: Born in Springfield, Ohio, October 6, 1947, son of John H. and June G. Hennessy; married Katie Bachrach June 14, 1969. Died in Salt Lake City, February 28, 1975.

Education: Attended Elm Place Elementary School in Highland Park, Illinois; graduated from Florida Central Academy in 1965; received a Bachelor of Arts degree in Sociology from Whittier College, Whittier, California, in 1970.

Professional Experience: Falconer for ten years, spent many years working with and rehabilitating injured birds of prey. Worked with kestrels for Dr. James A. Gessaman, Department of Biology, Utah State University, 1973.