Resource partitioning among three species of hawks in the Centennial Valley, Montana
by Marco Restani

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University
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Abstract:
Resource partitioning among red-tailed (Buteo iamaicensis), ferruginous (B_ regalis), and Swainson' s hawks (B. swainsoni) along habitat, food, and temporal dimensions was studied during the 1987 and 1988 nesting seasons. The study area encompassed 319 km2 and was located in the Centennial Valley of southwestern Montana. Eighty-six active nests were located over 2 years: 20 red-tailed, 24 ferruginous, and 42 Swainson's. Most (88%) nests were in foothill drainages and distance to nearest neighbor was significantly less than expected. Red-tailed hawks nested in trees significantly more often than ferruginous and Swainson's hawks. Red-tailed hawks nested in significantly taller substrates, deeper within stands, and at higher elevations than ferruginous and Swainson's hawks. Ferruginous and Swainson's hawks nested primarily in willows (Salix spp.).

Ferruginous hawk nests had significantly larger windows, more long distance exposure, and were at lower elevations than Swainson1s hawk nests. Slope aspects at all nests were predominantly oriented northwest or southeast. Nesting chronology of red-tailed and ferruginous hawks overlapped most while Swainson's hawks nested 3 weeks later. Mean fledging dates of red-tailed, ferruginous, and Swainson's hawks were 11 July, 15 July, and 5 August, respectively. Ferruginous hawks were the most productive and Swainson's hawks the least. Distance to nearest neighbor and potential sources of disturbance were not significantly correlated with reduced productivity. Ground squirrels (Spermophilus spp.) were the main prey of each species. Dietary overlap was greatest between red-tailed and ferruginous hawks and least between ferruginous and Swainson's hawks. Ferruginous hawks took significantly more mammals than red-tailed and Swainson's hawks. Red-tailed and ferruginous hawks took significantly more ground squirrels but fewer voles and birds than Swainson's hawks. Adult hawks of each species did not appear to partition foraging habitat or hunting activity periods. Juvenile red-tailed hawks had the longest post-fledging period and Swainson's hawks the shortest. Juveniles appeared to use habitats in proportion to their availability. Dispersal of juveniles of each species occurred the third week of August. Twenty-eight interspecific interactions were observed. Swainson's hawks were most aggressive and dominated in most (92%) encounters in which they were involved.

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of

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APPROVAL

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Resource partitioning among red-tailed (Buteo jamaicensis), ferruginous (B. regalis), and Swainson's hawks (B. swainsoni) along habitat, food, and temporal dimensions was studied during the 1987 and 1988 nesting seasons. The study area encompassed 319 km^2 and was located in the Centennial Valley of southwestern Montana. Eighty-six active nests were located over 2 years: 20 red-tailed, 24 ferruginous, and 42 Swainson's. Most (88%) nests were in foothill drainages and distance to nearest neighbor was significantly less than expected. Red-tailed hawks nested in trees significantly more often than ferruginous and Swainson's hawks. Red-tailed hawks nested in significantly taller substrates, deeper within stands, and at higher elevations than ferruginous and Swainson's hawks. Ferruginous and Swainson's hawks nested primarily in willows (Salix spp.). Ferruginous hawk nests had significantly larger windows, more long distance exposure, and were at lower elevations than Swainson's hawk nests. Slope aspects at all nests were predominantly oriented northwest or southeast. Nesting chronology of red-tailed and ferruginous hawks overlapped most while Swainson's hawks nested 3 weeks later. Mean fledging dates of red-tailed, ferruginous, and Swainson's hawks were 11 July, 15 July, and 5 August, respectively. Ferruginous hawks were the most productive and Swainson's hawks the least. Distance to nearest neighbor and potential sources of disturbance were not significantly correlated with reduced productivity. Ground squirrels (Spermophilus spp.) were the main prey of each species. Dietary overlap was greatest between red-tailed and ferruginous hawks and least between ferruginous and Swainson's hawks. Ferruginous hawks took significantly more mammals than red-tailed and Swainson's hawks. Red-tailed and ferruginous hawks took significantly more ground squirrels but fewer voles and birds than Swainson's hawks. Adult hawks of each species did not appear to partition foraging habitat or hunting activity periods. Juvenile red-tailed hawks had the longest post-fledging period and Swainson's hawks the shortest. Juveniles appeared to use habitats in proportion to their availability. Dispersal of juveniles of each species occurred the third week of August. Twenty-eight interspecific interactions were observed. Swainson's hawks were most aggressive and dominated in most (92%) encounters in which they were involved.

INTRODUCTION

Two species cannot occupy exactly the same niche (Grinnell 1917, Gause 1934). Coexisting species must separate along 1 or more resource dimensions in saturated habitat. In birds, resource partitioning occurs most commonly along habitat dimensions, followed by food, and then temporal dimensions (Lack 1971, Cody 1974, Schoener 1974).

Three species of buteos, red-tailed (Buteo jamaicensis), ferruginous (B. regalis), and Swainson's hawks (B. swainsoni), coexist in abundance in the Centennial Valley of southwestern Montana. Because the struggle for existence is generally most intense between species of the same genus (Darwin 1859), these hawks seemed appropriate subjects for a study of resource partitioning. Studies in Alberta (Schmutz et al. 1980) and Oregon (Cottrell 1981) reported resource partitioning along nesting habitat dimensions among these 3 species while broad overlap occurred in prey utilization and nesting chronology.

The purpose of this study was to record resource partitioning among these 3 hawk species in southwestern Montana. Objectives were to determine: (1) nest site characteristics, (2) nesting chronology, (3) prey utilization, (4) habitat use and foraging activity of adults and, (5) habitat use and dispersal of juveniles. Field work was conducted during 1987 and 1988.

STUDY AREA

Location and Physiography

The study area was located in the Centennial Valley of Beaverhead County in southwestern Montana with its western boundary approximately 16 km east of Lima. Its greatest north-south width (18 km) and east-west length (26 km) resulted in a study area 319 km^2 in size (Fig. 1). Land ownership was 44% private, 43% federal, and 13% state.

The study area, located in the western third of the Centennial Valley, is bordered to the north by the Snowcrest Range and to the south by the Centennial Mountains. Mountains, composed primarily of volcanic and sedimentary rocks, slope gently to the nearly level valley floor. Few rock outcrops occur. Four perennial streams occur on the study area, but the vast majority are ephemeral.

Lowest elevations (1,974 m above mean sea level) occurred beside Lima Reservoir. Highest elevations ranged from 2,544 m in the northeastern corner of the study area to 2,256 m in the south central region along the Continental Divide.

Geology and Soils

Physiography of the study area was determined during the Tertiary Period. Tensional block faulting uplifted the Centennial Mountains and the Snowcrest Range. The Centennial Valley is a block which has

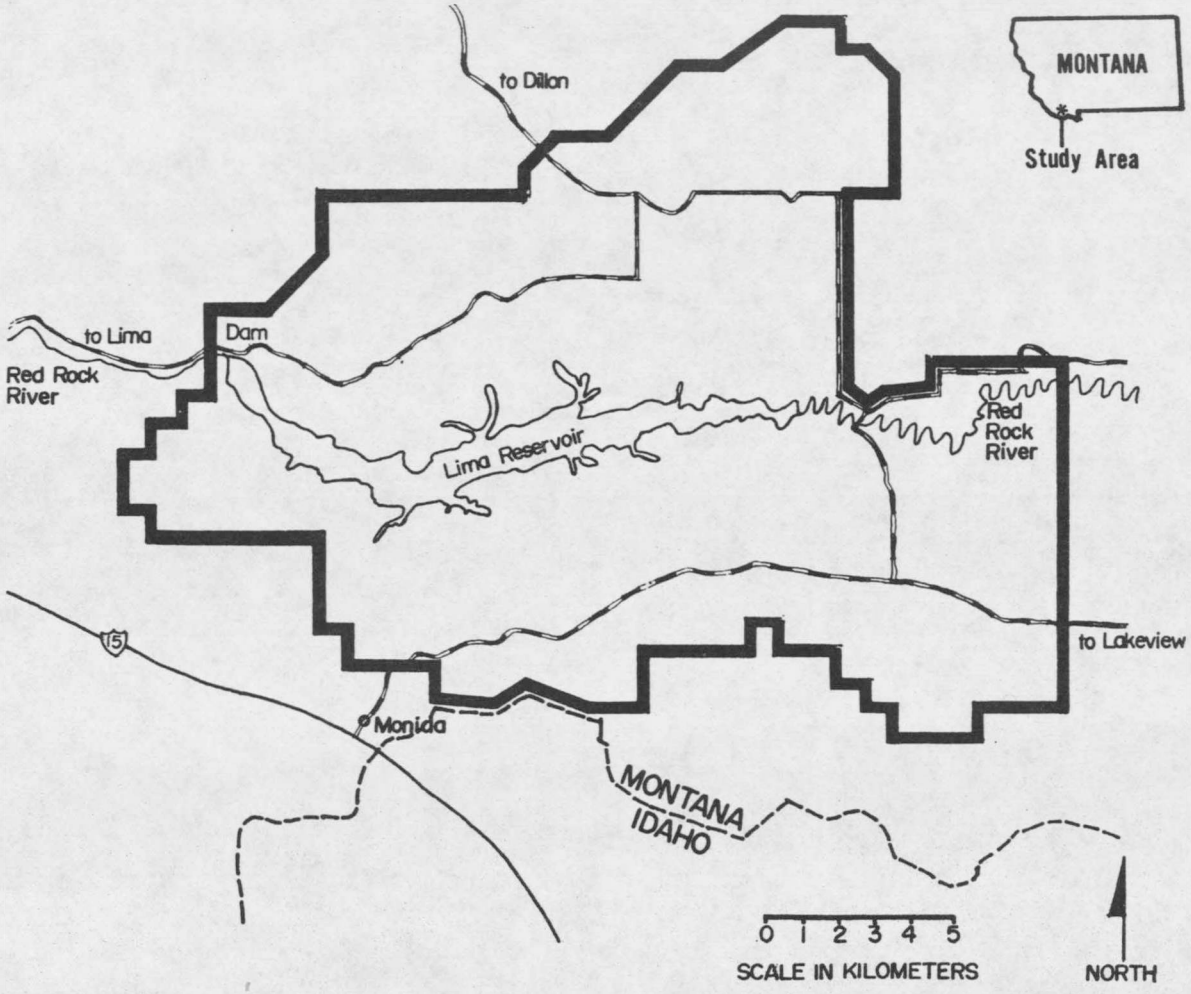


Figure 1. Location of the study area in the Centennial Valley, Montana.

been dropped and rotated (Witkind 1980). The area is prone to extensive mass movements.

Intermountain valleys formed during this time accumulated alluvial material. Sediments, dominated by calcium carbonate from limestone and clay from shale of surrounding mountains (Scholten et al. 1955, Veseth and Montagne 1980), have a montmorillontic mineralogy and exert the greatest influence on present day soils (Tippy et al. 1978).

Mollisols are the most common soil orders found on the study area. Aridic Argiborolls are found on the planar lacustrine basins adjacent to the eastern part of Lima Reservoir (Tippy et al. 1978). These clayey soils swell with water uptake. Soils surrounding the remainder of Lima Reservoir were formed from gravelly, calcareous alluvial deposits. Higher slopes are dominated by Calcic Cryoborolls which have a high calcium component and are rocky (Tippy et al. 1978). Soils on the study area are most suitable for rangeland grazing with only moderate potential for cultivation.

Precipitation from summer thunderstorms is absorbed by the alluvial sediments. Several springs are located in the alluvium next to the sedimentary mountains.

Climate and Weather

The study area is characterized by short, cool summers and long, cold winters. Annually an average of 27 cm of precipitation falls on Lima, more than 80% of which accumulates from April to August (Table 1). During the summer months, convective thunderstorms account for

Table 1. Monthly precipitation totals (cm) and departures from normal (cm) for weather stations near the Centennial Valley study area, Montana, 1987 and 1988.[a]

		April		May		June		July		August	
Station	Year	Ppt.	Dep.	Ppt.	Dep.	Ppt.	Dep.	Ppt.	Dep.	Ppt.	Dep.
Lakeview	1987	2.16	-1.73	9.04	3.05	4.78	-3.40	16.84	13.36	3.45	-0.74
	1988	7.26	3.38	5.54	-0.46	2.39	-5.79	1.70	-1.78	0.61	-3.58
Lima	1987	1.67	-0.79	10.57	5.99	4.83	-0.23	12.95	9.93	3.02	-0.13
	1988	3.99	1.55	4.98	0.41	0.71	-4.34	1.17	-1.85	1.85	-1.30
Monida	1987	2.01		10.52		5.16		13.16		2.39	
	1988	5.31		2.21		1.22		0.00		0.56	

[a] Data from the National Oceanic and Atmospheric Administration (NOAA) 1987, 1988.

most precipitation. These short-lived, mid-afternoon storms are localized. Winds are predominantly westerly and strongest during spring and fall transitions with upslope winds occurring during warm summer days.

January is the coldest month in Lima with an average temperature of -8.7 C and July, with an average temperature of 14.1 C, is the warmest month. Record high and low temperatures recorded at Lima were 29 C and -39 C, respectively (NOAA 1987, 1988).

Although the study period was characterized by drought, weather conditions differed between the 2 field seasons. During 1987, May and July received precipitation far above normal. Temperatures were above normal in late spring and early summer but fell below average later in the season. A heavy hailstorm on 22 June blanketed the northern half of the study area with ice.

During 1988, precipitation totals for June, July, and August were well below normal. Temperatures were above average for the entire

April-August period. The number of thunderstorms during summer was half that of 1987 and all were of less intensity. Lima Reservoir, which normally stretches 18 km, dried to a length of 5 km. Gusty winds were common throughout the summer.

Vegetation

The study area contained plant species typical of intermountain grassland areas. Shrubs common on the flats next to Lima Reservoir included Nuttall's saltbush (Atriplex nuttalii), low sagebrush (Artemisia arbuscula), winterfat (Ceratoides lanata), rubber rabbitbrush (Chrysothamnus nauseosus), greasewood (Sarcobatus vermiculatus), and gray horsebrush (Tetradymia canescens). A few small clumps of spindly willows (Salix spp.) bordered the reservoir. Grasses found in this area included thickspike wheatgrass (Agropyron dasystachyum), quackgrass (A. repens), western wheatgrass (A. smithii), bluebunch wheatgrass (A. spicatum), Idaho fescue (Festuca idahoensis), prairie junegrass (Koleria cristata), and Sandberg's bluegrass (Poa sandbergii). Dominant forbs were rose pussytoes (Antennaria microphylla), biennial sagewort (A. biennis), and silverweed cinquefoil (Potentilla anserina).

Mid-elevation alluvial slopes supported a grass-sagebrush complex. Dominant shrubs included big sagebrush (A. tridentata), three-tipped sage (A. tripartita), and rubber rabbitbrush. Wheatgrasses, Idaho fescue, needle-and-thread (Stipa comata), and prairie junegrass composed the understory. Stands of Douglas fir (Pseudotsuga menziesii) were rare.

Mountain streams were bordered with dense stands of large willows. Clumps of aspen (Populis tremuloides) occurred around seeps at higher elevations. Stands of Douglas fir, aspen, and lodgepole pine (Pinus contorta) covered high elevation north facing slopes.

Mammals and Birds

Twenty-four species of mammals were observed on the study area (Appendix, Table 20). Twelve species of rodents were noted. Two species of ground squirrels (Spermophilus spp.) were abundant on the valley floor. Six species of carnivores were recorded; all except the mink (Mustela vison) were considered common. Four species of ungulates used the study area.

Ninety-seven species of birds were observed on the study area (Appendix, Table 21), 65 of which were either regular users or breeders. Eight species of raptors nested on the study area. Lima Reservoir is important Canada goose (Branta canadensis) molting habitat; up to 9,000 geese use the area in June (Hildebrand 1979). Horned larks (Eremophila alpestris), western meadowlarks (Sturnella neglecta), and savannah (Passerculus sandwichensis) and vesper sparrows (Pooecetes gramineus) were common in grass-sagebrush communities. Black-billed magpies (Pica pica) were abundant in willow thickets. Northern flickers (Colaptes auratus) and European starlings (Sturnus vulgaris) were common in aspen groves.

Human Impacts

The population of Beaverhead County was 8,500 in 1986 (U.S. Department of Commerce (USDOC) 1988). Approximately 6,500 people live in the Dillon area, 67 km north of the study area. Ten people inhabit the study area during the summer months only. In 1986, population density for the 14,177 km^2 county was 1 person per 1.7 km^2. Economy of the county is based on crop and livestock production.

Historical use of the Centennial Valley has centered around rangeland grazing of sheep and cattle. Because of the harsh climate and poor soil quality, past attempts at small grain farming have met with limited success. Hay has not been harvested in the valley since the 1960's. Currently the study area is used only for summer cattle grazing. Most of the range is in good condition.

Water resources have been manipulated by damming and irrigation. Lower Red Rock dam, located east of the study area, was constructed in 1930. The dam on Lima Reservoir was built in 1902. Irrigation ditches are used throughout the study area during summer.

Logging for Douglas fir and lodgepole pine occurred during the 1960's and 1980's in mountain drainages adjacent to the study area. Phosphate was mined from 1956-1958 in Odell Creek, located 32 km east of the study area, but recovery was discontinued due to the high cost of transport. Potential for gas and oil development is low. A thin bed of coal exists in the western Centennial mountains.

With only a few gravel roads to provide access, the Centennial Valley is remote. With the exception of hunting in late fall,

recreational activities are restricted to nearby Red Rock Lakes National Wildlife Refuge which reports an average of 6,000 visitor days per year (B. Reiswig, pers. comm. 1986).

METHODS

Nest Searches and Visits

Field work was conducted from 13 June - 31 August 1987 and 13 April - 25 August 1988. Terminology used to describe hawk nests and reproductive success follows Postupalsky (1974). The study area was systematically searched on foot and active hawk nests plotted on 7.5-minute U.S. Geological Survey (USGS) topographic maps. When possible, clutch size and hatching date were recorded for active nests. Ferruginous hawks, which are prone to nest desertion if disturbed during incubation (Fyfe and Olendorff 1976), were not approached during the early nesting period. After young had gained full thermoregulatory capabilities (1-3 weeks old), nests were visited every 2-5 days to observe nestling growth, determine causes of nestling loss, and gather prey remains. Nests were not checked during cold (<10 C), wet weather.

Nesting Habitat Description

A nest site was defined as the nest substrate and the area within a 200-m radius. In late August after young had fledged, 27 direct measurements and qualitative descriptions were recorded to characterize nest sites (Table 2). Shortest distance from the nest to the periphery of the stand was measured to characterize nest tree location in the stand. Long distance exposure (LDE) was the degree

Table 2. Characteristics measured at and around red-tailed, ferruginous, and Swainson's hawk nest sites on the Centennial Valley study area, Montana, 1987 and 1988.

Parameter	Method of measurement
A. Nest spacing	
1. Distance to nearest conspecific nest	USGS topographic map
2. Distance to nearest congeneric nest	USGS topographic map
B. Nest substrate characteristics	
3. Nest substrate	Observation
4. Nest substrate height	Stratex stratolevel
5. Nest substrate DBH[a]	DBH tape
6. Nest substrate decadence	Observation (estimate to nearest percentage)
7. Shortest distance to stand edge from nest[b]	100 m measuring tape
C. Nest characteristics	
8. Nest height	Stratex stratolevel
9. Nest position	Compass
10. Nest window direction	Compass
11. Nest window size	Compass
12. Long distance exposure[b]	Compass
13. Nest dimensions	Carpenter's rule
14. Nest materials[b]	Observation (estimate to nearest percentage)
D. Nest site characteristics	
15. Slope aspect at nest substrate	Compass
16. Percent slope at nest substrate	Stratex stratolevel
17. Elevation at nest substrate	USGS topographic map
18. Stand density[b]	Point-centered quarter
19. Mean stand height	Stratex stratolevel
20. Description of vegetation types[b]	Observation (estimate to nearest percentage)
E. Disturbance	
21. Improved gravel road	Observation and USGS topographic map for parameters 21-27
22. Jeep trail	
23. Grazing	
24. Occupied house	
25. Occupied barn	
26. Abandoned building	
27. Other	

[a] Diameter at breast height.
[b] Described in text.

width of the view from the center of the nest (window) unobstructed 200 m or more from the nest (Ensign 1983). Type and amount of materials used to construct the nest were identified and estimated.

Stand density around hawk nests was calculated using the point-centered quarter method (Cottam and Curtis 1956). This method was used only as an index to compare relative tree densities among nest sites. Each stand was subjectively categorized as a ribbon or clump. Ribbons stands were typical of those bordering a stream. In ribbon stands, 2 transects 45 m long were established from the nest substrate, one upstream and one downstream. Six sample points were located every 15 m. At each sample point the surrounding area was divided into 4 quadrants. Species, distance, and height were recorded for the closest tree or willow in each quadrant. Clump stands were typical of those around a spring. Clump stands were sampled by 2 transects 30 m long in opposite directions from the nest tree on the long axis of the clump. Two 15-m transects were also located in opposite directions from the nest tree perpendicular to the 30-m transects.

Vegetation within a 100-m radius from each nest was described by estimating the percentage of ground covered by grass/forbs, sagebrush, willows, and trees. Human and grazing activities and man-made structures within a 1,000-m radius from each nest were recorded to assess potential disturbance.

Prey Utilization

Prey utilized by each hawk species was determined by analysis of castings, recording prey items in the nest, and direct observation. Prey items were recorded and checked against prey data collected earlier to minimize duplication. Castings gathered at nest and adult perch sites were air dried and stored in labeled ziploc bags. Dried castings were separated and bones and feathers identified by comparison with specimens in the Montana State University Vertebrate Museum. Prey remains were also identified using mammalian keys (Hoffman and Pattie 1968, Maser and Storm 1970). Prey were identified to the lowest taxonomic category practical. Weights of prey used in biomass calculations were from Johnsgard (1973), Banfield (1974), and Steenhof (1983).

To census the relative abundance of small mammal species, 20 transects were established in representative habitats. Transects were 50 m long and oriented in a north-south direction. Each transect included 5 trap stations located 10 m apart. A trap station consisted of 2 Museum Special snap traps, 1 Victor M4 rat trap, and 1 Sherman Live trap. Traps were placed 1 m from the sample point in a manner maximizing the distance between each trap.

Trapping was conducted once a month in July and August 1987 and May-August 1988. Traps were set for 3 consecutive nights for a total of 7,080 trap nights. Snap traps were baited with peanut butter and live traps with oats. Traps were checked and baited every morning and captured animals identified and removed from the area.

Capture, Marking, and Monitoring

During 1988, 5 adult hawks were captured and fitted with radio transmitters. Hawks were captured using a pigeon harness (Webster 1976), a bal-chatri baited with a pigeon (Columba livia) (Berger and Mueller 1959), padded leg-hold traps baited with ground squirrels and white-tailed jackrabbits (Lepus townsendii) following Harmata (1985), and Dho-gaza nets set with a live great horned owl (Bubo virginianus) (Meredith 1943).

Captured hawks were hooded with a rufter hood and processed by 2 persons. Hawks were fitted with U.S. Fish and Wildlife Service (USFWS) lock-on leg bands on the right leg. Calipers were used to measure foot pad length, hallux claw length, tarsal width, gape, eye diameter, culmen length, and bill depth. Leg and foot measurements were taken on the left leg. Eye color and pattern were described and photographed.

Wing and tail tracings were made after Harmata (1984). Wing chord, wingspan, and 8th primary length were measured with a carpenter's rule. Tail length was measured ventrally with a carpenter's rule and molt noted. Observations of ectoparasites and shock marks were recorded.

Hawks were fitted with 3-stage radio transmitters (AVM Instrument Co., Ltd., Dublin, CA) powered by 3.5-volt lithium batteries. Estimated transmitter life was 120 days and frequencies were between 150.800 and 151.900 Megahertz (MHz).

Transmitters were encased in dental acrylic. A flexible whip antenna 25.0 cm long was reinforced at the base with 4.5 cm of coiled spring. Transmitter packages weighed 32 grams (g) and had dimensions 5.8 x 2.0 x 2.0 cm. Two holes 3 mm in diameter were bored 4.0 cm apart through the base of the transmitter package perpendicular to the long axis. A 40-cm length of 7-mm teflon tubing (Bally Ribbon Mills, Bally, PA) was passed through each hole, centered, and knots tied adjacent to the transmitter to prevent movement of the tubing through the transmitter.

Transmitters were mounted as a backpack. Lateral straps were passed anterior and posterior to the humerus on both sides. The four strap ends were temporarily held in place on the breast with a hemostat while adjusting the strap lengths for proper fit. Once a snug fit was obtained the straps were sewn together with 2 stitches of 100% cotton thread. Use of cotton thread facilitates shedding of the transmitter. Strap ends were trimmed, glued, and taped. Processing time averaged 45 minutes and hawks were released at the site of capture.

During 1988, juvenile hawks were banded with USFWS lock-on leg bands prior to fledging. Seven juvenile hawks were fitted with radio transmitters similar to adults.

Radio-tagged hawks were monitored with a 5-element, hand held, yagi antenna and telemetry receiver. Monitoring strategy for adults was to locate an individual, make visual contact, and track it visually for 4 hours (h) with telemetry facilitating locations if the hawk was out of sight. Observations of habitat use and activity were

recorded. Juveniles were located daily to record their habitat use and dispersal. Attempts were made to locate all radio-tagged hawks every day. Locations were plotted with a grease pencil on acetate covered USGS topographic maps and later transferred to tracing paper overlays. Adult home ranges were determined using the minimum area method (Mohr 1947).

Raptor Community Composition

Locations and activities of all raptors were recorded at least twice a week to determine raptor community composition. The nature of raptor interactions was described, noting location, aggressor species, and outcome.

Data Analysis

The nearest neighbor method (Clark and Evans 1954) was used to determine spacing of hawk nests. The ratio of observed to expected distance between nests ("R" value) provides an index of spacing. Distance between nests is maximum when R=2.15, random when R=1.0, and under conditions of maximum aggregation R=0.0. Nest site data were analyzed using one-way analysis of variance (ANOVA), chi-square, and two-tailed t tests (Snedecor and Cochran 1980). Prey utilization data were analyzed using chi-square tables. Productivity data and fledging data were analyzed used two-tailed t tests and ANOVA. Tukey's multiple comparison was used to determine differences among hawks in ANOVA. Tests were considered statistically significant if $p<0.05$.

Niche breadth of nest substrate use was calculated for each hawk species using Levins' (1968) formula: $B=1/\Sigma\ p_i^2$ where p_i is the relative occurrence of a substrate type for a hawk species. Index values range from 1 to n. This formula was also used to determine diet diversity.

Niche overlap among hawk species for nest substrate use was calculated using Pianka's (1973) formula: $\alpha=\Sigma\ p_i q_i/(\Sigma\ p_i^2\ \Sigma\ q_i^2)^{1/2}$ where p_i is the relative use of substrate i by 1 species and q_i is its relative use by the second species. Index values range from 0 (no overlap) to 1 (complete overlap). This formula was also used to determine diet overlap.

RESULTS

Nest Site

Eighty-six active hawk nests were located: 11 red-tailed, 13 ferruginous, and 21 Swainson's during 1987 and 9 red-tailed, 11 ferruginous, and 21 Swainson's during 1988. Although I could easily identify inactive ferruginous hawk nests, I had trouble distinguishing between inactive red-tailed and Swainson's hawk nests. Therefore, only active nests were considered in analyses unless otherwise noted.

Ten nests were found on the valley floor and 76 in foothill drainages leading to the valley. Five drainages contained nests of each species and 6 contained nests of 2. Two drainages contained only 2 pairs of Swainson's hawks.

Four nest sites were occupied by different hawk species during 1987 and 1988. One nest site occupied by a red-tailed hawk pair which failed in 1987 was occupied by a successful pair of ferruginous hawks during 1988. A ferruginous hawk nest which failed in 1987 was successfully used by a pair of Swainson's hawks during 1988. Two successful Swainson's hawk nest sites in 1987 were occupied by ferruginous hawks during 1988.

Mean distance between all nests in 1987 was 1.12 km (SD=0.95 km), significantly closer than expected (R=0.84, p=0.043). Occupied nest density was 1 nest/7.1 km^2 during 1987. Mean distance between all nests in 1988 was 1.02 km (SD=0.82 km), approximately 25% closer than

expected (R=0.73, p=0.001). Occupied nest density was 1 nest/7.8 km^2 during 1988.

Characteristics of nest spacing are presented in Table 3. During 1987, red-tailed and Swainson's hawks nested closer than expected to conspecifics, although not significantly (p=0.810 and p=0.682, respectively). Ferruginous hawks nested farther apart than expected from conspecifics, but the difference was not significant (p=0.374). Each hawk species nested significantly closer than expected to congeners (red-tailed, p=0.037; ferruginous, p<0.001; Swainson's, p=0.032).

Table 3. Distance to nearest neighbor and density of red-tailed, ferruginous, and Swainson's hawk nests on the Centennial Valley study area, Montana, 1987 and 1988.

Year	Hawk species	Nearest conspecific nest (km) Mean	SD	R value	Nearest congeneric nest (km) Mean	SD	R value	Density (km^2/nest)
1987	Red-tailed	2.74	2.80	0.96	1.93	2.42	0.67	29.0
	Ferruginous	2.82	2.44	1.13	0.92	0.70	0.37	21.3
	Swainson's	1.80	1.16	0.95	1.42	1.33	0.75	14.5
1988	Red-tailed	3.09	2.77	1.07	0.87	0.21	0.30	29.0
	Ferruginous	2.98	1.40	1.03	0.92	0.64	0.32	21.3
	Swainson's	1.71	1.04	0.90	1.47	1.32	0.78	13.3

During 1988, only Swainson's hawks nested closer than expected to conspecifics, although not significantly (p=0.412). Red-tailed and ferruginous hawks nested significantly closer than expected to

congeners ($p<0.001$ and $p<0.001$, respectively). Although Swainson's hawks nested closer than expected to congeners, the difference was not statistically significant ($p=0.056$).

Each hawk pair maintained a minimum distance from conspecific nests but nested closer to congeners. Closest red-tailed hawk nests were 0.6 km apart, those of ferruginous hawks 1.0 km, and Swainson's hawks nested as close as 0.8 km apart. Red-tailed hawks nested as close as 0.4 km from congeners, and both ferruginous and Swainson's hawks nested as close as 0.2 km from congeners.

No statistically significant differences were found in nest site characteristics between years within species. Therefore, data from both seasons were combined for comparisons among the 3 species unless otherwise noted. Data for each year are presented in Appendix, Tables 22-27.

Ferruginous hawks nested on the widest variety of substrates and Swainson's hawks the narrowest (Fig.2). However, red-tailed hawks had the largest substrate niche breadth (2.06), with ferruginous hawks intermediate (1.87), and Swainson's hawks smallest (1.05).

Red-tailed hawks nested significantly more in trees and less in willows than both ferruginous and Swainson's hawks ($p<0.001$). Although Swainson's hawks nested in willows more and trees less than ferruginous hawks, the difference was not statistically significant ($p=0.059$). Nest substrate overlap was highest between ferruginous and Swainson's hawks (97.2%), intermediate between red-tailed and ferruginous hawks (31.3%), and lowest between red-tailed and Swainson's hawks (29.2%).

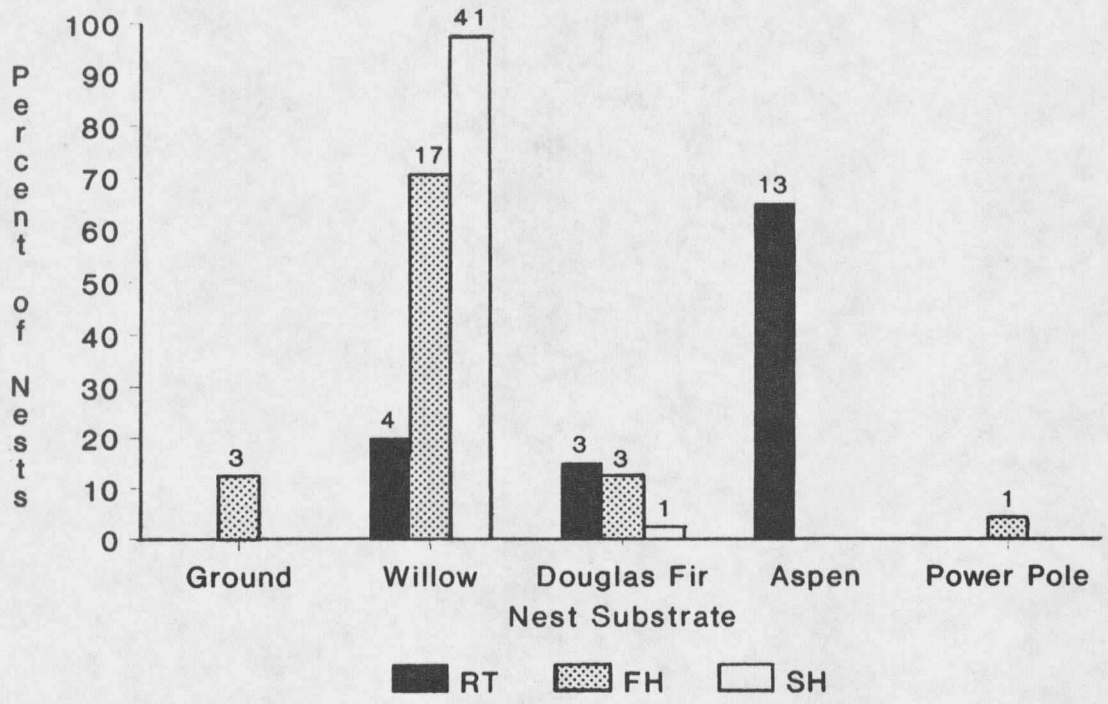


Figure 2. Substrates of red-tailed (RT), ferruginous (FH), and Swainson's hawk (SH) nests on the Centennial Valley study area, Montana, 1987 and 1988. Sample sizes indicated above bars.

Characteristics of nest substrates are presented in Table 4. Nest substrates of red-tailed hawks were significantly taller than those of the other 2 species ($p<0.001$).

DBH data were not compared among species because of small sample sizes. Mean DBH of red-tailed hawk aspen substrates was 37 cm (SD=7cm) and that of fir substrates 19 cm (SD=5 cm). DBH of ferruginous hawk fir substrates averaged 29 cm (SD=1 cm). One pair of Swainson's hawks nested in a fir (DBH=23 cm).

Decadence of red-tailed hawk nest substrates was usually confined to large lower limbs. Although mean percent decadence of ferruginous

Table 4. Substrate characteristics of red-tailed, ferruginous, and Swainson's hawk nests on the Centennial Valley study area, Montana, 1987 and 1988.

Hawk species	Height (m)		DBH (cm)[a]		Decadence (%)		Shortest dist. to stand edge (m)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Red-tailed	13.9	5.9	34	10	14	16	11.2	9.1
Ferruginous	5.2	2.3	27	5	30	30	3.5	3.6
Swainson's	5.1	1.2			24	27	3.6	2.4

[a] Diameter at breast height.

hawk nest substrates was greater than Swainson's hawk nest substrates, almost two thirds were less than 20% decadent. Differences in decadence among the 3 hawk species were not significant ($p=0.119$). However, red-tailed hawks nested significantly farther from stand edges than ferruginous and Swainson's hawks ($p<0.001$).

Characteristics of nests are presented in Table 5. Red-tailed hawk nests were located significantly higher off the ground than ferruginous and Swainson's hawk nests ($p<0.001$).

Table 5. Characteristics of red-tailed, ferruginous, and Swainson's hawk nests on the Centennial Valley study area, Montana, 1987 and 1988.

Hawk species	Height on substrate (m)		Window size (°)		LDE (°)[a]		Dimensions (LXW) (cm)[b] Nest		Bowl	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Red-tailed	8.9	3.6	48	27	23	29	86X65	18X19	42X32	16X10
Ferruginous	3.9	2.2	124	115	68	50	127X98	26X30	58X45	16X6
Swainson's	3.8	1.1	38	25	14	22	79X64	15X12	40X33	7X7

[a] Long distance exposure.
[b] Length X width.

Nest position on substrate varied widely for each hawk species (Fig. 3). Four ferruginous hawk nests were constructed directly on top of willows and thus had no directional orientation. Thirty-three (78%) Swainson's hawk nests were positioned between 40° and 206°. Five nests had no directional orientation.

The majority of red-tailed hawk nest windows were oriented either southeast or west (Fig. 4). Direction of ferruginous hawk nest windows showed no pattern. Four ferruginous hawk nests, 3 ground and 1 power pole, were accessible from any direction. The majority of Swainson's hawk nest windows faced south. Access to 3 nests was gained from the top only. Nest windows of ferruginous hawks were significantly wider than those of red-tailed and Swainson's hawks ($p<0.001$).

Relative nest exposure was determined by measuring long distance exposure (LDE). Ferruginous hawk nests had significantly more LDE than the other 2 species ($p<0.001$). LDE of ferruginous hawk nests was almost 66% larger than that of red-tailed hawk nests.

Red-tailed hawk nests were constructed of aspen, willow, sagebrush, and fir twigs. Nest bowls were lined with strips of fine bark from aspen, willow, or sagebrush. Fresh leafy sprigs of aspen and fir were commonly found in bowls.

The largest ferruginous hawk nest measured 185 X 160 cm. It rose 150 cm from the rock substrate and had been added to over several seasons. The smallest ferruginous hawk nest, measuring 75 X 75 cm, was constructed on a power pole platform originally intended to attract ospreys (Pandion haliaetus). Although nest materials were

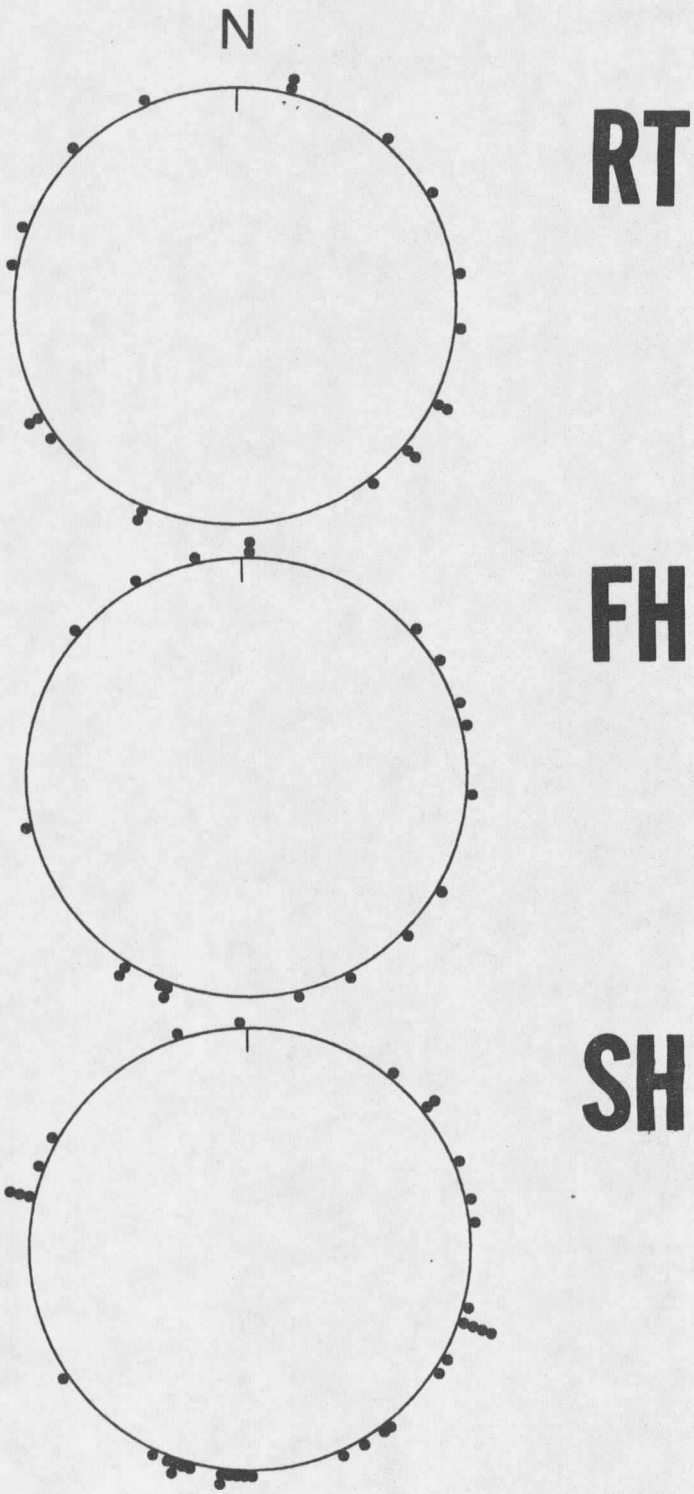


Figure 3. Position on substrate of red-tailed (RT), ferruginous (FH), and Swainson's hawk (SH) nests on the Centennial Valley study area, Montana, 1987 and 1988.

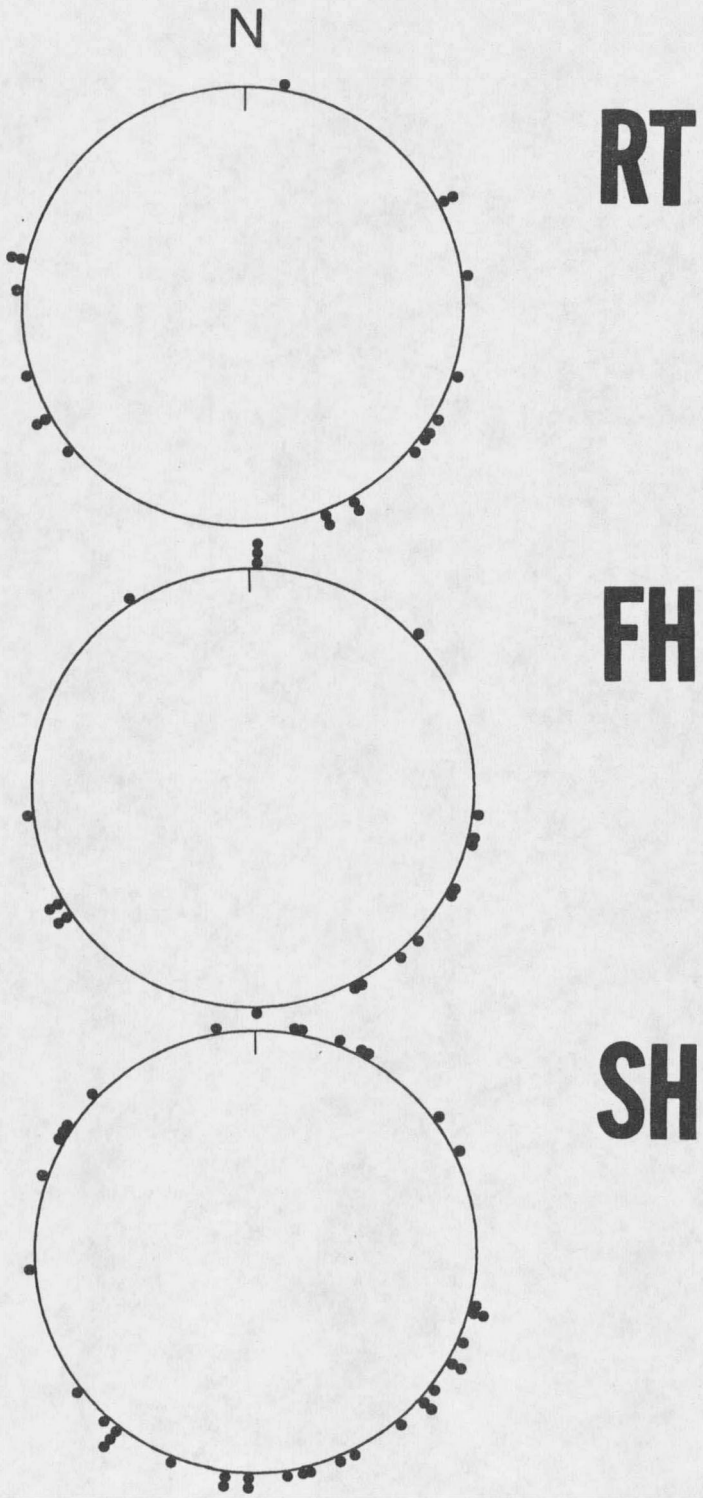


Figure 4. Window direction of red-tailed (RT), ferruginous (FH), and Swainson's hawk (SH) nests on the Centennial Valley study area, Montana, 1987 and 1988.

predominantly sagebrush twigs, some nests contained 50% willow sticks. Bowls were lined with sagebrush and willow bark and those in fir trees contained fresh fir twigs. Thirteen nests (54%) had cow or horse dung as a bowl component. One nest was located on top of an active magpie nest.

Swainson's hawk nests in willows were constructed of sagebrush and willow twigs, the former largely confined to the base. Bowls were lined with strips of sagebrush and willow bark. One nest in a fir was constructed of fir twigs. Ten (24%) Swainson's hawk nests were located on top of inactive magpie nests.

Each hawk species reused nests with equal probability ($p=0.550$). Four red-tailed hawk nests, all in aspen, were used both years. Three ferruginous hawks nests, 2 in willows and 1 in a fir, were used both years. Swainson's hawks reused 4 willow nests from 1987 to 1988.

Slope aspects at nest locations were predominantly in 2 directions, northwest and southeast (Fig. 5). Differences among species were not apparent.

Characteristics of nest sites are presented in Table 6. Seventy-six (88%) hawk nests were located on terrain with less than 20% slope. Red-tailed hawk nests were located on the steepest slopes because they were constructed in aspens at the heads of drainages generally. Ground nests of ferruginous hawks were on much steeper slopes ($\bar{x}=24\%$, SD=6%) than other nests of this species. Differences among species were not significant ($p=0.134$).

Elevation at nest locations differed significantly among the hawk species ($p=0.008$). Nest sites ranged in elevation from 2,010 m to

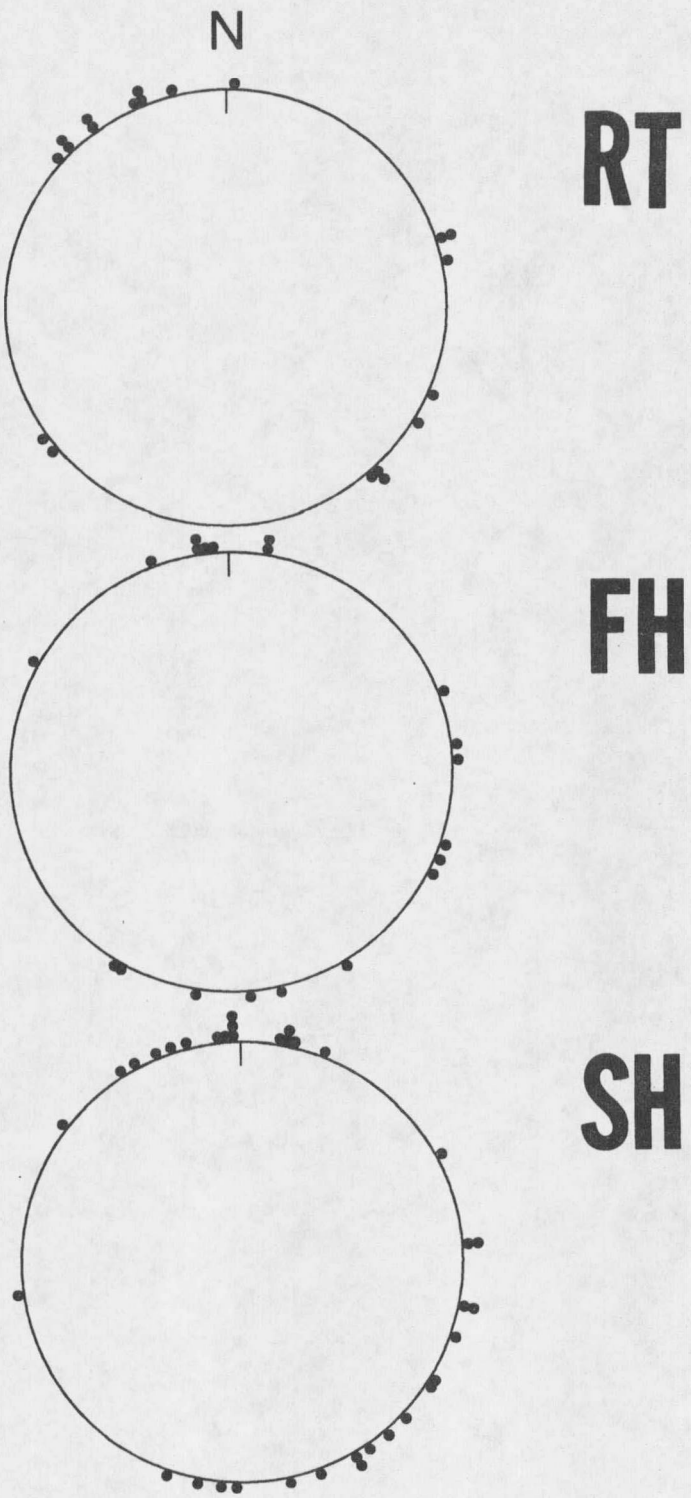


Figure 5. Slope aspect at red-tailed (RT), ferruginous (FH), and Swainson's hawk (SH) nests on the Centennial Valley study area, Montana, 1987 and 1988.

Table 6. Characteristics of red-tailed, ferruginous, and Swainson's hawk nest sites on the Centennial Valley study area, Montana, 1987 and 1988.

Hawk species	Slope (%)		Elevation (m)		Stand Density (trees/ha)		Stand Height (m)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Red-tailed	11	8	2,125	66	620	403	7.3	3.2
Ferruginous	10	10	2,075	36	352	376	3.9	2.3
Swainson's	7	8	2,105	53	645	560	3.9	0.8

2,288 m. In the 5 drainages which contained nests of each species, red-tailed hawks nested highest in elevation, ferruginous hawks lowest adjacent to the valley floor, and Swainson's hawks in between. Six drainages contained nests of 2 species. Regardless of the species combination, the same relationship of nest location occurred with respect to elevation.

Although differences were not statistically significant ($p=0.056$), the relative stand density around nests differed substantially among the species. However, mean tree height around red-tailed hawk nests was significantly taller than that of the other 2 species ($p<0.001$).

Vegetation composition within a 100-m radius from each nest varied among species (Table 7). Vegetation around red-tailed hawks nests was composed of significantly more aspen than that around ferruginous and Swainson's hawk nests ($p<0.001$). Willow and sagebrush composition around nests did not differ among hawk species ($p=0.448$ and $p=0.995$, respectively). Vegetation around ferruginous and

Table 7. Vegetation composition (%) around red-tailed, ferruginous, and Swainson's hawk nests on the Centennial Valley study area, Montana, 1987 and 1988.

Hawk species	Aspen		Willow		Sagebrush		Grass/forb	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Red-tailed	18	19	12	13	22	11	49	15
Ferruginous	0	0	10	7	21	16	69	14
Swainson's	0	0	12	6	21	15	66	15

Swainson's hawk nests had a significantly higher composition of grass/forbs than that around red-tailed hawk nests ($p<0.001$).

Distances to potential sources of disturbance within 1,000 m of nests were measured and sources classified into road, building, and grazing categories. Each hawk species nested within 1,000 m of roads with equal probability ($p=0.323$). Eight red-tailed hawk nests averaged 450 m (SD=242 m) from roads. Ferruginous hawks nested closest to roads ($\bar{x}$=315 m, SD=231, n=14). Seventeen Swainson's hawk nests averaged 415 m (SD=178 m) from roads. Eleven of the 14 (79%) ferruginous hawk nests could be viewed from the road and although not statistically significant ($p=0.054$), it was substantially more than red-tailed (50%) and Swainson's hawk nests (55%).

Ferruginous hawks nested near buildings significantly more than red-tailed hawks ($\bar{x}$=582 m, SD=297 m and $\bar{x}$=825, SD=170 m, respectively $p=0.010$). The difference with Swainson's hawks was not statistically significant ($\bar{x}$=638 m, SD=225 m, $p=0.075$). Two ferruginous and 3 Swainson's hawk nests could be viewed from occupied houses.

Red-tailed hawks nested in grazed areas significantly less than ferruginous and Swainson's hawks ($p=0.003$ and $p=0.002$, respectively). Only 3 red-tailed hawk nests were in areas subjected to grazing. No difference was found between ferruginous and Swainson's hawks in their preference or avoidance of grazed areas ($p=0.925$).

Because ferruginous and Swainson's hawks nested primarily in willows, a t-test was conducted on nest site variables of willow sites only. As with ANOVA, statistically significant differences existed between the 2 species with respect to window size and LDE. In addition, ferruginous hawks nested significantly lower in elevation than Swainson's hawks ($p=0.042$).

Reproduction

Red-tailed, ferruginous, and Swainson's hawks initially arrive in the Centennial Valley in late March and early April (J. Balcomb, pers. comm. 1989). Red-tailed hawks arrive first, followed by ferruginous and Swainson's hawks. Arrival dates were 2 weeks earlier during 1988 than in 1987.

Field work began too late in 1987 (13 June) to observe incubation and egg hatch. By back-dating from fledging dates, I determined that red-tailed and ferruginous hawks began to lay eggs in late April. Eggs hatched during late May and early June. Swainson's hawks laid eggs 2 weeks later, during the third week of May, with eggs hatching in mid-June.

Observations of early nesting activities were made during 1988. One red-tailed hawk was observed low in a nest on 1 May, presumably

incubating. Of 5 nests visited on 28 and 29 May, 4 contained 1 nestling a few days old and 1 contained 1 nestling and 2 eggs; the latter nest fledged 3 young. Fledging dates during 1988 supported the observations that red-tailed hawks laid eggs in late April and that hatching started in late May.

Two ferruginous hawks were observed low in nests on 30 April and 8 May 1988. A female was observed feeding and brooding small nestlings on 2 June. Another nest containing 2 young was discovered on 2 June. These data and fledging dates indicated that the nesting cycle of ferruginous hawks began 1 week earlier in 1988 than in 1987. Egg laying probably started in mid-April with clutches beginning to hatch in late May.

One adult Swainson's hawk was seen carrying nesting material on 1 May 1988. A nest adjacent to the study area contained 2 nestlings on 23 June. On 30 June, a nest on the study area contained 1 small nestling and 1 egg. One nest checked on 5 July contained 1 nestling and another 1 nestling and 1 egg. Egg laying and hatching were 1 week later in 1988 than 1987. During 1988, Swainson's hawks laid eggs in late May with incubation lasting until late June.

No differences were found in productivity within species between years (Table 8). Therefore, data were combined for comparisons among species.

The 48 territories occupied during 1987 were increased to 50 in 1988 with the addition of 2 Swainson's hawk territories. Percent active territories dropped from 1987 to 1988 for each species. Red-tailed hawks showed the most dramatic decrease in activity (18%).

Table 8. Productivity of red-tailed, ferruginous, and Swainson's hawks on the Centennial Valley study area, Montana, 1987 and 1988.

Statistic	Red-tailed			Ferruginous			Swainson's		
	1987	1988	1987-88	1987	1988	1987-88	1987	1988	1987-88
Total occupied territories	11	11	22	15	15	30	22	24	46
Total active nests	11	9	20	13	11	24	21	21	42
Percent active nests (occupied)	100	82	91	87	73	80	95	88	91
Total successful nests (occupied)	8	7	15	9	11	20	18	18	36
Percent successful nests (occupied)	73	64	68	60	73	67	82	75	78
Percent successful nests (active)	73	78	75	69	100	83	86	86	86
Total young in nests	14	21	35	29	30	59	28	32	60
Total young fledged	14	19	33	24	29	53	26	32	58
Productivity (occupied)	1.27	1.73	1.50	1.60	1.93	1.77	1.18	1.33	1.26
Productivity (active)	1.27	2.11	1.65	1.85	2.64	2.21	1.24	1.52	1.38
Productivity (successful)	2.00	2.71	2.20	2.67	2.64	2.65	1.44	1.78	1.61

Ferruginous hawks had the lowest nest success and Swainson's hawks the highest. Differences among species for percent active nests and nest success were not significant ($p=0.248$ and $p=0.476$, respectively).

Despite a decrease in percent active nests, productivity of each species increased from 1987 to 1988. Although Swainson's hawks fledged the most young, they had the lowest productivity. Ferruginous hawks were most productive. Differences in productivity per occupied territory were not significant ($p=0.205$). However, ferruginous hawks were significantly more productive per active nest than Swainson's hawks ($p=0.018$). Both red-tailed and ferruginous hawks fledged significantly more young per successful nest than Swainson's hawks ($p<0.001$).

No red-tailed hawk nest examined contained more than 3 eggs. One young fledged from 1 nest, 2 young fledged from 7 nests each, and 3 young fledged from 6 nests each.

Three ferruginous hawks fledged from 10 nests each and 4 young fledged from 3 nests each. A brood of 5 was the largest observed. Of 3 ground nests, 1 failed, 1 young fledged from 1, and 3 fledged from 1.

Clutches of 2 were most commonly recorded in Swainson's hawk nests. However, the majority of nests contained only 1 young. Only 3 nests, all in 1988, contained 3 nestlings each.

Productivity of each hawk species was evaluated with respect to potential sources of disturbance (Table 9). Success and productivity of nests within 1,000 m of roads was not different than that of nests located farther away ($p=0.550$ and $p=0.428$, respectively). Success and

Table 9. Productivity of red-tailed, ferruginous, and Swainson's hawks in relation to potential sources of disturbance on the Centennial Valley study area, Montana, 1987 and 1988.

	Distance to nest from:					
	Roads		Buildings		Grazing	
	≤1,000 m	>1,000 m	≤1,000 m	>1,000 m	≤1,000 m	>1,000 m
Red-tailed	1.38	1.83	[a]	1.63	[a]	1.77
Ferruginous	2.21	2.25	2.36	2.00	2.33	2.10
Swainson's	1.48	1.32	1.53	1.30	1.48	1.26

[a] Not calculated due to small sample sizes (n=3).

productivity of red-tailed hawk nests within 1,000 m of buildings and grazing could not be determined due to small sample sizes.

Success and productivity of ferruginous hawk nests within 1,000 m of roads was not different than that of nests located farther away (p=0.711 and p=0.949, respectively). The same relationship existed between nests within 1,000 m and those farther away from buildings (success, p=0.160; productivity, p=0.270) and grazing (success, p=0.139; productivity, p=0.691).

Success and productivity of Swainson's hawk nests within 1,000 m of roads was not different than that of nests located farther away (p=0.199 and p=0.568, respectively). Nest success and productivity were not different between nests within 1,000 m of buildings and those located farther away (p=0.280 and p=0.708, respectively). Nests in areas subjected to grazing were as successful and productive as nests not in grazed areas (p=0.734 and p=0.734, respectively).

The potential impact neighboring pairs had on success and productivity of other nests was tested. Nests ≤0.3 km from other

nests were tested against those >0.3 km distant from other nests. No red-tailed hawk nests were ≤0.3 km from other nests. Because sample sizes were small for ferruginous and Swainson's hawks, data were combined. Nests ≤0.3 km from other nests were as successful as those farther away (p=0.892). Nests ≤0.3 km from other nests fledged a mean 1.40 young while those more distant fledged 1.73 young (p=0.400).

Sixteen nests of all species were visible from other nests. Nests within sight of other nests were as successful and productive as nests visually obstructed (p=0.604 and p=0.604, respectively). Nests within sight of other nests fledged a mean 1.56 young and those visually obstructed 1.71 young. Each species nested within view of other active nests with equal probability (p=0.527).

Egg loss accounted for the greatest decrease in productivity of red-tailed hawks. Four nests in 1987 contained eggs which never hatched. During 1988, 1 nest containing 2 eggs was blown out of a tree during May. The adults constructed and defended a "frustration" nest (Postupalsky 1974). Two small nestlings died of exposure during 1988. Trapping disturbance near the nest most likely caused the deaths.

During 1987, a ferruginous hawk ground nest was discovered containing broken eggs. The nest was located 10 m from a jeep trail used by ranchers in early May. Five nestlings were killed before fledging during 1987. Two young, 30-35 days old, were found partially consumed below nests. Predation by golden eagle (Aquila chrysaetos) was indicated. In an unusual case, 3 young, 35-40 days old, were found trampled within 3 m of a very low willow nest. Yearling cattle

may have frightened the young and caused them to jump from the nest prematurely.

During 1988, a very small ferruginous hawk nestling was found dead in a nest, a victim of fratricide or starvation. Three much larger siblings survived to fledging. One nest containing 2 young was blown completely out of a willow during the third week of June 1988. Both young survived and continued to be fed by the adults on the pile of sticks on the ground. The 2 young fledged successfully on 8 July.

One Swainson's hawk nestling, approximately 30 days old, was found partially consumed in a nest in 1987. Predation by golden eagle was suspected. One nestling was found dead hanging below a nest, its wing wedged in a forked branch. Two nests contained eggs which never hatched. Desertions may have been due to my early nest visits. In each case the incubating female was frightened from the nest.

Mean fledging dates of red-tailed hawks during 1987 and 1988 were 12 and 11 July, respectively (Fig. 6). The difference was not significant ($p=0.497$). However, red-tailed hawks fledged over a greater range during 1987 (3-18 July) than 1988 (8-13 July). Ferruginous hawks fledged from 12-27 July 1987 ($\bar{x}$=18 July). Although this was a full week later than during 1988 (range 2-20 July, $\bar{x}$=11 July), the difference was not statistically significant ($p=0.066$). Swainson's hawks fledged significantly earlier during 1987 (range 28 July - 10 August, $\bar{x}$=2 August) than 1988 (range 31 July - 20 August, $\bar{x}$=2 August, $p=0.010$).

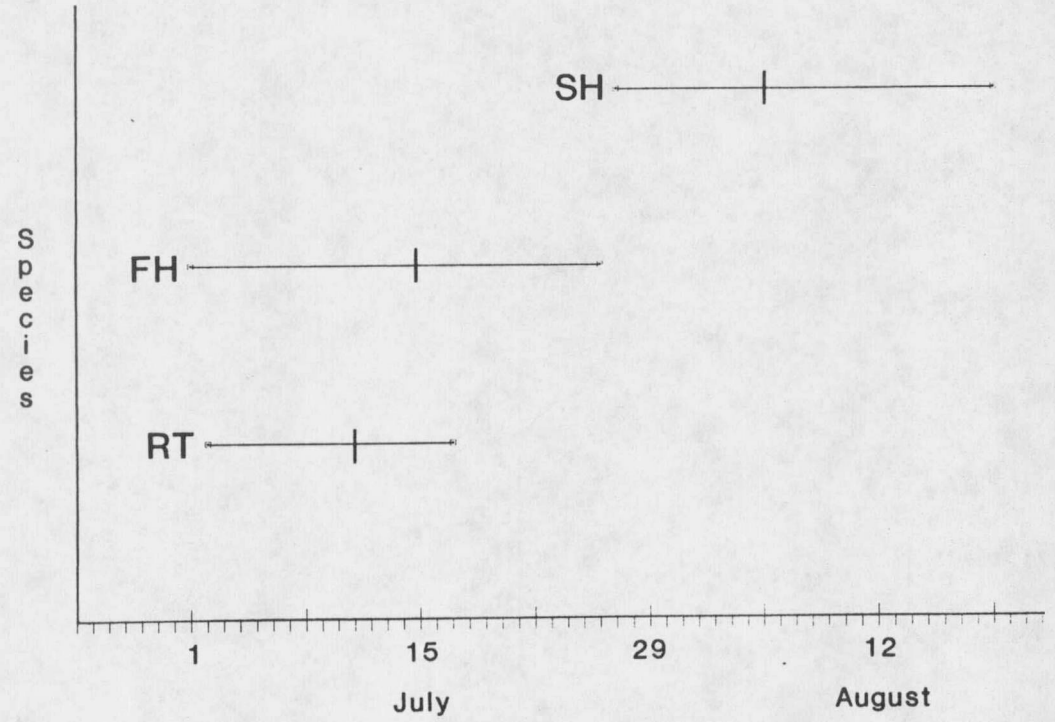


Figure 6. Range and mean date of fledging of red-tailed (RT), ferruginous (FH), and Swainson's hawks (SH) on the Centennial Valley study area, Montana, 1987 and 1988 combined.

Prey Utilization

Data on prey use were collected primarily from remains gathered in and below nests (Tables 10-12). Observations of hawks killing prey and collections from perch sites were few. Red-tailed hawk prey remains were collected from 16 nests during 31 visits with 87 vertebrate individuals identified to species or genus. Remains were collected from 23 ferruginous hawk nests during 49 visits with 176 vertebrate individuals identified to species or genus. Prey remains were collected from 25 Swainson's hawk nests during 60 visits. From

Table 10. Prey of red-tailed hawks based on remains collected at nests and perch sites on the Centennial Valley study area, Montana, 1987 and 1988.

Taxon	1987 N	1987 %	1988 N	1988 %	Total N	Total %
Mammals						
Ground squirrel (*Spermophilus* spp.)	5	27.8	39	49.4	44	45.4
Voles (*Microtus* spp.)	0	0.0	12	15.2	12	12.3
Northern pocket gopher (*Thomomys talpoides*)	3	16.7	3	3.8	6	6.2
Sagebrush vole (*Lagurus curtatus*)	1	5.6	1	1.3	2	2.1
Deer mouse (*Peromyscus maniculatus*)	0	0.0	1	1.3	1	1.0
White-tailed jackrabbit (*Lepus townsendii*)	0	0.0	1	1.3	1	1.0
Unidentified small mammals	1	5.6	1	1.3	2	2.1
Total mammals	10	55.7	58	73.6	68	70.1
Birds						
Northern flicker (*Colaptes auratus*)	1	5.6	4	5.1	5	5.2
European starling (*Sturnus vulgaris*)	1	5.6	4	5.1	5	5.2
Western meadowlark (*Sturnella neglecta*)	1	5.6	4	5.1	5	5.2
Vesper sparrow (*Pooecetes gramineus*)	0	0.0	2	2.5	2	2.1
Blue grouse (*Dendragapus obscurus*)	0	0.0	1	1.3	1	1.0
American robin (*Turdus migratorius*)	1	5.6	0	0.0	1	1.0
Unidentified passerines	1	5.6	0	0.0	1	1.0
Other unidentified birds	2	11.1	2	2.5	4	4.1
Total birds	7	39.1	17	21.6	24	24.8
Reptiles						
Snakes (*Thamnophis* spp.)	0	0.0	2	2.5	2	2.1
Total reptiles	0	0.0	2	2.5	2	2.1
Insects						
Coleoptera	1	5.6	2	2.5	3	3.1
Total insects	1	5.6	2	2.5	3	3.1
Total prey items	18		79		97	

Table 11. Prey of ferruginous hawks based on remains collected at nests and perch sites on the Centennial Valley study area, Montana, 1987 and 1988.

Taxon	1987 N	1987 %	1988 N	1988 %	Total N	Total %
Mammals						
Ground squirrels (*Spermophilus* spp.)	53	52.0	65	73.9	118	62.1
Voles (*Microtus* spp.)	8	7.9	5	5.6	13	6.8
Northern pocket gopher (*Thomomys talpoides*)	6	5.9	5	5.7	11	5.8
Sagebrush vole (*Lagurus curtatus*)	3	2.9	3	3.4	6	3.2
Deer mouse (*Peromyscus maniculatus*)	4	3.9	0	0.0	4	2.1
White-tailed jackrabbit (*Lepus townsendii*)	1	1.0	2	2.3	3	1.6
Cow (*Bovus* spp.)	1	1.0	0	0.0	1	0.5
Unidentified small mammal	1	1.0	0	0.0	1	0.5
Total mammals	77	75.6	80	90.9	157	82.6
Birds						
Western meadowlark (*Sturnella neglecta*)	7	6.9	4	4.5	11	5.8
European starling (*Sturnus vulgaris*)	3	2.9	2	2.3	5	2.6
Savannah sparrow (*Passerculus sandwichensis*)	2	2.0	0	0.0	2	1.1
Black-billed magpie (*Pica pica*)	1	1.0	0	0.0	1	0.5
Vesper sparrow (*Pooecetes gramineus*)	1	1.0	0	0.0	1	0.5
Unidentified passerines	3	2.9	0	0.0	3	1.6
Other unidentified birds	0	0.0	2	2.3	2	1.1
Total birds	17	16.7	8	9.1	25	13.2
Insects						
Coleoptera	4	3.9	0	0.0	4	2.1
Orthoptera	4	3.9	0	0.0	4	2.1
Total insects	8	7.8	0	0.0	8	4.2
Total prey items	102		88		190	

Table 12. Prey of Swainson's hawks based on remains collected at nests and perch sites on the Centennial Valley study area, Montana, 1987 and 1988.

Taxon	1987 N	1987 %	1988 N	1988 %	Total N	Total %
Mammals						
Ground squirrels (*Spermophilus* spp.)	34	31.8	21	30.9	55	31.4
Voles (*Microtus* spp.)	33	30.8	7	10.3	40	22.9
Northern pocket gopher (*Thomomys talpoides*)	3	2.8	10	14.7	13	7.4
Sagebrush vole (*Lagurus curtatus*)	3	2.8	0	0.0	3	1.7
Deer mouse (*Peromyscus maniculatus*)	2	1.9	0	0.0	2	1.1
Striped skunk (*Mephitis mephitis*)	1	0.9	0	0.0	1	0.6
White-tailed jackrabbit (*Lepus townsendii*)	1	0.9	0	0.0	1	0.6
Unidentified small mammals	1	0.9	1	1.5	2	1.1
Total mammals	78	72.8	39	57.4	117	66.8
Birds						
Sage grouse (*Centrocercus urophasianus*)	2	1.9	5	7.4	7	4.0
European starling (*Sturnus vulgaris*)	4	3.7	2	2.9	6	3.4
Western meadowlark (*Sturnella neglecta*)	4	3.7	2	2.9	6	3.4
Blue grouse (*Dendragapus obscurus*)	1	0.9	2	2.9	3	1.7
Black-billed magpie (*Pica pica*)	0	0.0	3	4.4	3	1.7
Vesper sparrow (*Pooecetes gramineus*)	2	1.9	1	1.5	3	1.7
American kestrel (*Falco sparverius*)	0	0.0	1	1.5	1	0.6
Northern flicker (*Colaptes auratus*)	1	0.9	0	0.0	1	0.6
Yellow-bellied sapsucker (*Sphyrapicus varius*)	1	0.9	0	0.0	1	0.6
Horned lark (*Eremophila alpestris*)	1	0.9	0	0.0	1	0.6
Sage thrasher (*Oreoscoptes montanus*)	0	0.0	1	1.5	1	0.6
Savannah sparrow (*Passerculus sandwichensis*)	0	0.0	1	1.5	1	0.6

Table 12. Continued.

Taxon	1987 N	1987 %	1988 N	1988 %	Total N	Total %
Birds						
Lark bunting (*Calamospiza melanocorys*)	1	0.9	0	0.0	1	0.6
Unidentified passerines	5	4.7	6	8.8	11	6.3
Other unidentified birds	0	0.0	1	1.5	1	0.6
Total birds	22	20.4	25	36.8	47	27.0
Reptiles						
Snakes (*Thamnophis* spp.)	1	0.9	0	0.0	1	0.6
Total reptiles	1	0.9	0	0.0	1	0.6
Insects						
Orthoptera	6	5.6	4	5.9	10	5.7
Total insects	6	5.6	4	5.9	10	5.7
Total prey items	107		68		175	

this collection, 151 vertebrate individuals were identified to species or genus.

Significant differences were noted in diets of ferruginous and Swainson's hawks between 1987 and 1988. Ferruginous hawks took significantly more mammals than other prey ($p=0.005$) and significantly more ground squirrels ($p<0.001$) during 1987 than 1988. Swainson's hawks took significantly more mammals than other prey ($p=0.033$) and significantly more voles (*Lagurus* and *Microtus* spp.) ($p=0.001$) during 1987 than 1988. Swainson's hawks took significantly fewer birds during 1987 than 1988 ($p=0.018$). Data from both years were combined into 4 classes of prey for comparisons among hawk species (Fig. 7).

Red-tailed hawks included 10 species and 2 genera of mammals and birds, 1 reptile genus, and 1 insect order in their diet. Red-tailed

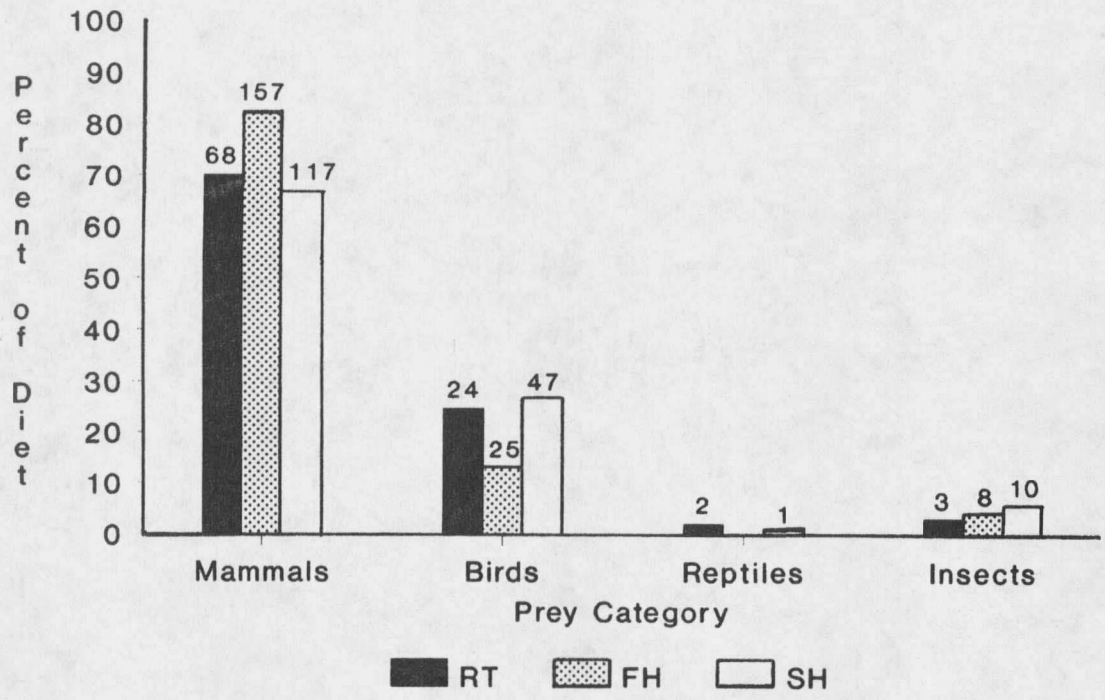


Figure 7. Prey by taxonomic class of red-tailed (RT), ferruginous (FH), and Swainson's hawks (SH) on the Centennial Valley study area, Montana, 1987 and 1988. Sample sizes indicated above bars.

hawks had a food niche breadth of 4.24. Ferruginous hawks had the smallest food niche breadth (2.50) represented by 10 species and 2 genera of mammals and birds and 2 insect orders. Swainson's hawks had the largest food niche breadth (6.11). Diet included 18 species and 2 genera of mammals and birds, 1 reptile genus, and 1 insect order.

Dietary overlap was greatest between red-tailed and ferruginous hawks (97.5%) and least between ferruginous and Swainson's hawks (86.0%). Diets of red-tailed and Swainson's hawks overlapped 92.7%. Although overlaps were great, differences in diet composition existed among the hawk species. Ferruginous hawks took significantly

more mammals than red-tailed ($p=0.015$) and Swainson's hawks ($p=0.001$). No difference was noted between red-tailed and Swainson's hawks ($p=0.583$).

Ground squirrels were the most important prey of each hawk species. Ground squirrels composed 45.4% of the diet of red-tailed hawks. The diet of ferruginous hawks contained the largest amount of ground squirrels (62.1%) and that of Swainson's hawks the smallest (31.4%). Red-tailed hawks took significantly more ground squirrels than Swainson's hawks ($p=0.022$). Ferruginous hawks took significantly more ground squirrels than red-tailed ($p=0.007$) and Swainson's hawks ($p<0.001$).

The second most commonly taken prey by each species was voles. No difference existed between red-tailed and ferruginous hawk use of voles ($p=0.266$). Swainson's hawks took significantly more voles than red-tailed ($p=0.049$) and ferruginous hawks ($p<0.001$). Mammalian composition of hawk diets is presented in Figure 8.

Birds composed 24.8%, 13.2%, and 27.0% of the diet of red-tailed hawks, ferruginous, and Swainson's hawks, respectively. No statistical difference existed between red-tailed and ferruginous hawk use of birds as prey ($p=0.704$). Swainson's hawks took significantly more birds than red-tailed ($p=0.014$) and ferruginous hawks ($p=0.001$). Passerines were the most common avian order taken by each hawk species. All northern flicker remains recovered from red-tailed hawk kills were collected from aspen clump nests. Western meadowlarks were the most frequently taken avian prey of ferruginous hawks. No large birds were taken. Swainson's hawks took 3 blue (Dendragapus

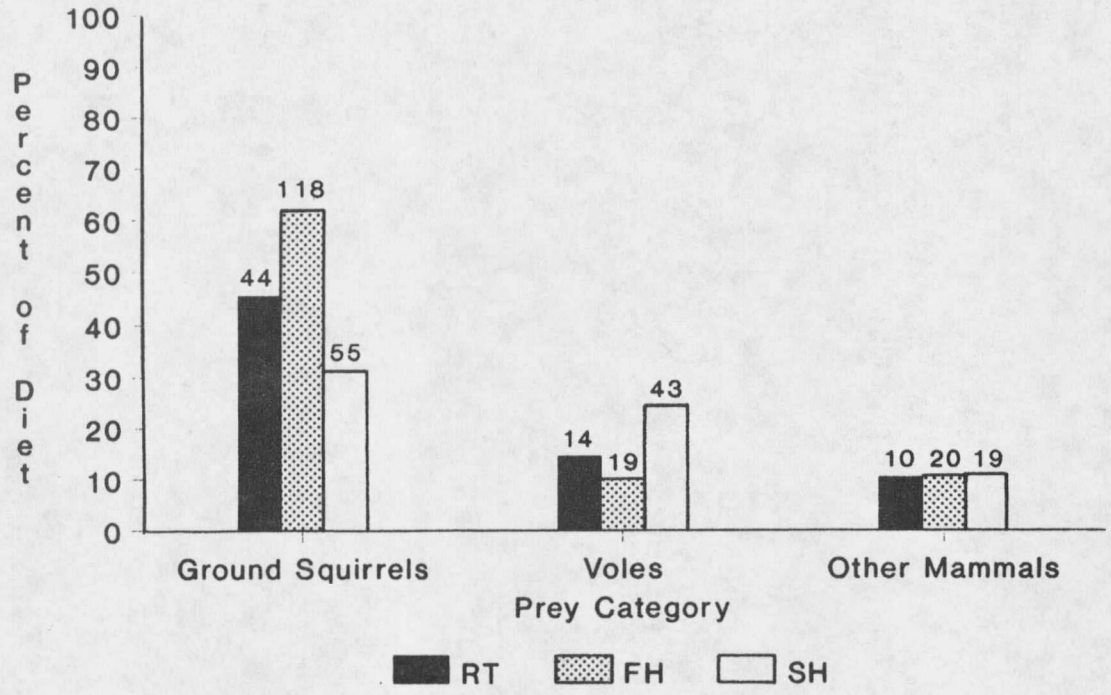


Figure 8. Mammalian prey of red-tailed (RT), ferruginous (FH), and Swainson's hawks (SH) on the Centennial Valley study area, Montana, 1987 and 1988. Sample sizes indicated above bars.

obscurus) and 7 sage grouse (Centrocercus urophasianus). Two of the blue and all of the sage grouse remains were recovered in late August. Sage grouse remains were collected from the same territory during 1987 and 1988.

Snakes were the only reptilian prey recorded. Insects were insignificant as prey. Coleopterans recovered from castings probably represented food of prey rather than items sought by hawks. However, orthopterans were recovered almost intact in castings and likely represented food of hawks.

The 5 prey which contributed most to percent biomass in hawk diets are presented in Table 13. Ground squirrels were the most important prey item of each hawk species.

Table 13. Five prey which contributed most to percent biomass (% B) in red-tailed, ferruginous, and Swainson's hawk diets on the Centennial Valley study area, Montana, 1987 and 1988.

Red-tailed		Ferruginous		Swainson's	
Prey item	% B	Prey item	% B	Prey item	% B
Ground squirrels	70.6	Ground squirrels	77.5	Ground squirrels	42.0
W-t jackrabbit[a]	13.4	W-t jackrabbit[a]	16.5	Sage grouse	26.7
Blue grouse	4.0	N. pocket gopher	1.8	Striped skunk	8.6
Voles	2.4	W. meadowlark	1.6	W-t jackrabbit[a]	6.4
N. pocket gopher	2.4	Voles	1.1	Blue grouse	5.7
Total	92.8		98.5		89.4

[a] White-tailed jackrabbit.

Prey Populations

During 1987 and 1988, 143 small mammals were trapped in 7,080 trapnights (Table 14). Deer mice (Peromyscus maniculatus) were most common, representing 69.8% of the catch. Deer mice were common in habitats with <10% sagebrush cover. Ground squirrels, representing 21.7% of the catch, were second most common. Ground squirrels were found in grass-sagebrush habitats and were most active during mid-morning and mid-afternoon. The majority of ground squirrels estivated during the third week of July. Nontarget species included 1 long-tailed weasel (Mustela frenata) and 12 vesper sparrows.

White-tailed jackrabbits were rare on the study area and not censused. Sightings increased from 1987 to 1988.

Table 14. Small mammals trapped on the Centennial Valley study area, Montana, 1987 and 1988.

Taxon	May 1987	May 1988	June 1987	June 1988	July 1987	July 1988	August 1987	August 1988
Masked shrew (Sorex cinereus)	0		0		4	0	0	1
Ground squirrels (Spermophilus spp.)	3		16		7	4	0	1
Least chipmunk (Eutamias minimus)	0		0		0	0	1	0
Northern pocket gopher (Thomomys talpoides)	0		0		1	0	0	0
Deer mouse (Peromyscus maniculatus)	13		17		27	15	11	16
Meadow vole (Microtus pennsylvanicus)	0		0		1	0	0	0
Sagebrush vole (Lagurus curtatus)	0		0		0	1	4	0
Total small mammals	16		33		40	20	16	18

Western meadowlarks were the most common passerine found on the study area. Black-billed magpies were abundant in willow thickets. Northern flickers and European starlings were common in aspen stands. Sage and blue grouse were uncommon, although blue grouse nested on the study area.

Adult Movements and Habitat Use

Five hawks were captured and radio-tagged during 1988 (Table 15). Morphological measurements are presented in Appendix, Table 28. Mated status, length of monitoring period, and size of home range are presented in Table 16. Although none of the captured hawks were active nesters, RT-832 was mated and observed copulating and SH-253 constructed and occupied a nest.

Table 15. Age, sex, and capture data of adult red-tailed, ferruginous, and Swainson's hawks radio-tagged on the Centennial Valley study area, Montana, 1988.

Date of capture	Hawk species	Age-sex[a]	Transmitter frequency (MHz)	Method of capture	Time of capture
5/2/88	Ferruginous	ASY-M	151.412	Bal-chatri	2025
5/6/88	Swainson's	ASY-F	151.253	Pigeon harness	0800
5/9/88	Red-tailed	ASY-F	151.832	Pigeon harness	1845
5/30/88	Red-tailed	ASY-M	151.776	Bal-chatri	1540
6/4/88	Ferruginous	SY-F	150.825	Pigeon harness	1440

[a] ASY=after second year, SY=second year, M=male, F=female.

Table 16. Mated status, monitoring period, and home range size of adult red-tailed, ferruginous, and Swainson's hawks radio-tagged on the Centennial Valley study area, Montana, 1988.

Hawk[a]	Mated status	Inclusive dates of monitoring	Minimum home range size
RT-776	unmated	6/2	N/A[b]
RT-832	mated	5/10-8/11	53.6 km^2
FH-412	unmated	5/3-8/12	84.6 km^2
FH-825	unmated	6/11-8/6	22.0 km^2
SH-253	mated	5/7-8/15	5.3 km^2

[a] Designation related to species and radio frequency in Table 15.
[b] RT-776 tracked 1 day only before signal lost.

I was unsuccessful in locating RT-776 on 31 May and 1 June. RT-776 was observed between 1443 and 1750 h on 2 June. Activity occurred over 2.3 km^2 of grassland with 5-10% sagebrush cover. Four unsuccessful strikes were observed, each initiated from a post perch.

The radio signal of RT-776 was lost and never relocated after it flew north behind a mountain ridge.

RT-832 foraged over hilly grasslands with <20% sagebrush cover and roosted in Douglas fir stands. FH-412 and FH-825 used valley floor grasslands with <5% and <10% sagebrush cover, respectively. Both roosted on the valley floor, presumably on the ground. SH-253 used a dense sagebrush covered slope adjacent to its nest extensively but foraged over valley floor grasslands. Roosts were in willows 100 m from the nest.

Unmarked congeneric adult hawks often foraged over the same area simultaneously. Congeners often perched within 200 m of each other when away from nest sites.

RT-832 was most active between 0900 and 1100 h, with a brief period of activity between 1300 and 1400 h. FH-412 was most active in early morning (0500-0700) and between 1500 and 1600 h. FH-825 was active during mid-morning (0900-1000) and late afternoon (1700-1900). SH-253 was most active between 1000 and 1200 h.

Home ranges of radio-tagged hawks are shown in (Fig. 9). Radio-tagged hawks used several types of perches (Fig. 10).

Red-tailed hawks hunted from perches, low altitude (<20 m) flapping flights, and kiting. Ferruginous hawks hunted from low altitude flapping flights and soars. Strikes from perches were not recorded. Swainson's hawks hunted from low altitude soars and perches. Strikes from kiting were common during windy conditions. Observed strikes as related to time period are displayed in Figure 11. Most strikes (70%) were executed on the valley floor.

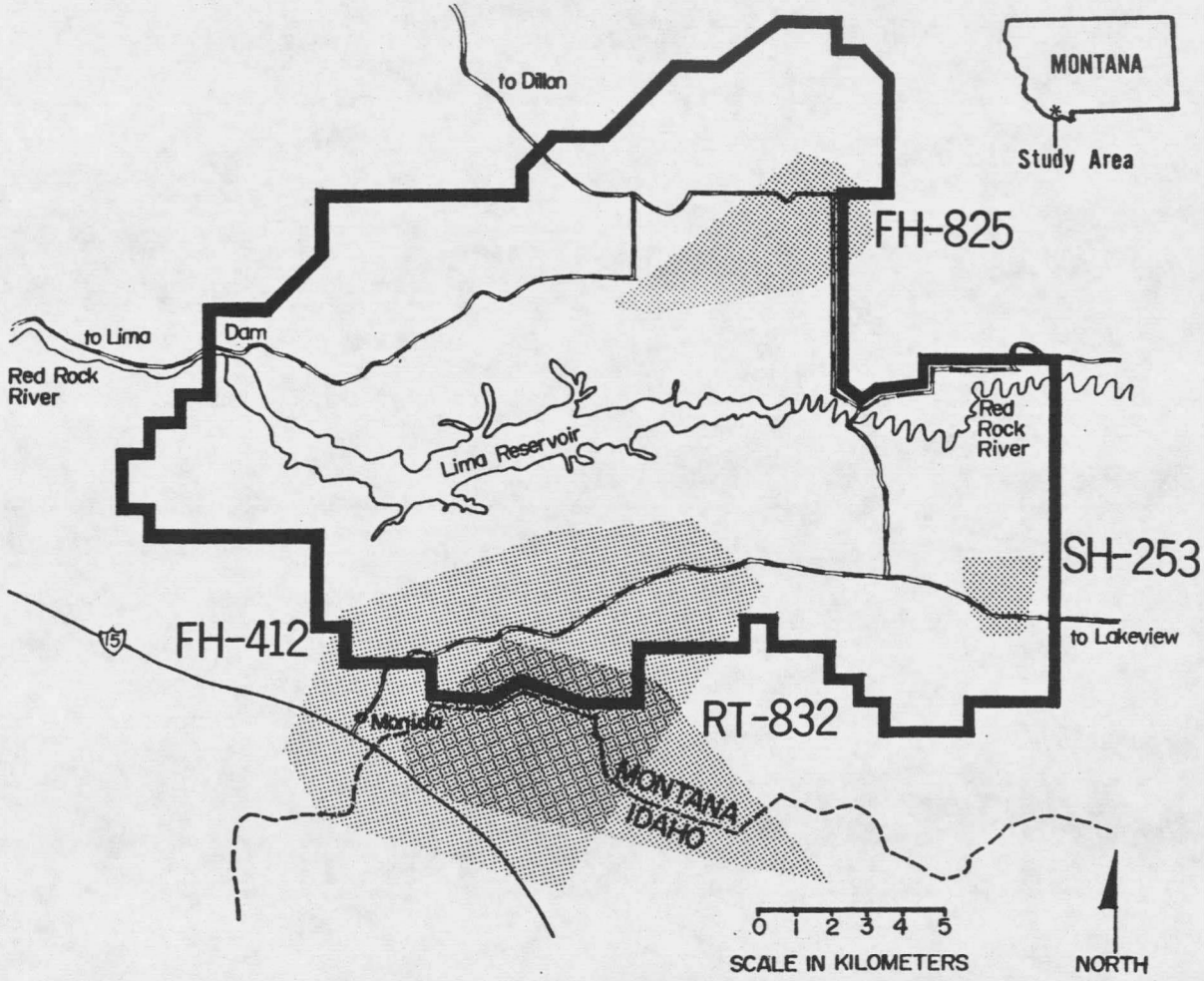


Figure 9. Home ranges of 4 radio-tagged adult red-tailed (RT), ferruginous (FH), and Swainson's hawks (SH) on the Centennial Valley study area, Montana, 1988.

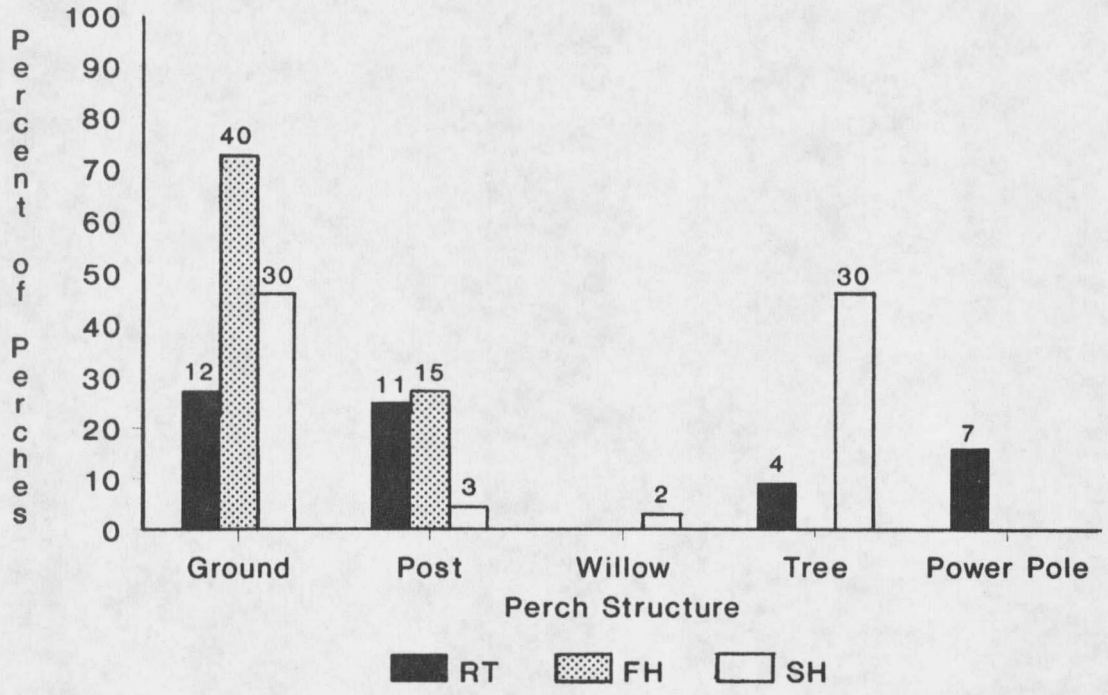


Figure 10. Perch structure of radio-tagged adult red-tailed (RT), ferruginous (FH), and Swainson's hawks (SH) on the Centennial Valley study area, Montana, 1988. Sample sizes indicated above bars.

Adult mortality was observed twice on the study area. During 1987, a female Swainson's hawk was discovered hanging in a willow below a nest, its neck wedged between a forked branch. A female red-tailed hawk was electrocuted during 1988.

Juvenile Movements and Habitat Use

Seven juvenile hawks were radio-tagged during 1988 (Table 17). Morphological measurements are presented in Appendix, Table 29.

Post-fledging period is the time between fledging and young hawk independence from adults. Post-fledging distances from nests of

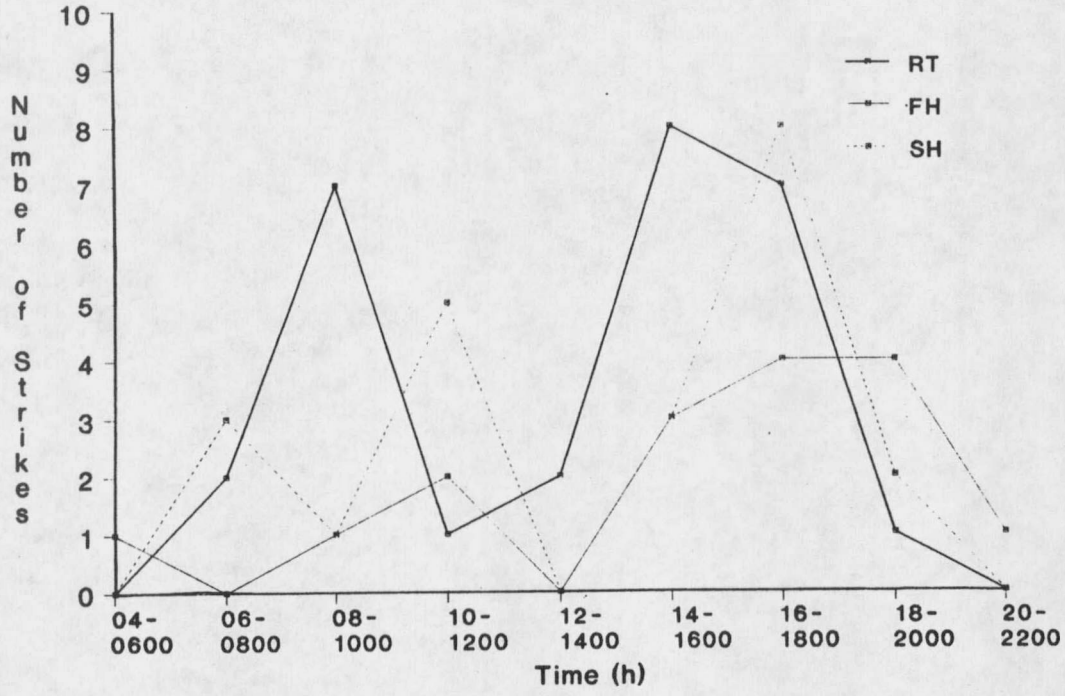


Figure 11. Number of strikes at prey related to time of day of red-tailed (RT), ferruginous (FH), and Swainson's hawks (SH) on the Centennial Valley study area, Montana, 1987 and 1988.

radio-tagged juvenile hawks are presented in Figure 12. RT-742 and RT-888 had post-fledging periods of 39 and 40 days, respectively. Ferruginous hawks had shorter post-fledging periods: FH-033, 28 days; FH-853, 26 days; FH-967, 10 days. FH-967 was found dead from starvation. SH-537 and SH-687 had post-fledging periods of 19 and 7 days, respectively. The radio transmitter package and harness of SH-687 was discovered intact. Predation by golden eagle was indicated.

Radio-tagged juvenile red-tailed hawks used grasslands with <20% sagebrush cover after fledging. Juveniles were often observed perched

Table 17. Selected characteristics of juvenile red-tailed, ferruginous, and Swainson's hawks radio-tagged on the Centennial Valley study area, Montana, 1988.

Hawk species	Transmitter frequency (MHz)	Date fledged	Number of siblings
Red-tailed	151.742	7/11/88	1
Red-tailed	150.888	7/11/88	2
Ferruginous	151.033	7/15/88	2
Ferruginous	151.853	7/10/88	2
Ferruginous	150.967	7/20/88	1
Swainson's	151.537	8/5/88	1
Swainson's	151.687	8/8/88	0

on rocks during the first week. Flight was mastered the second week and radio-tagged juveniles were often observed soaring with siblings and parents. Activity shifted away from the nest site during the third week. Habitat use was concentrated in grasslands with <5% sagebrush cover. Juveniles were often found perched on posts with siblings or parents. RT-742 was last observed with adults 32 days after fledging. RT-888 was last seen with adults and siblings 36 and 40 days after fledging, respectively.

Radio-tagged juvenile ferruginous hawks used habitats similar to juvenile red-tailed hawks. Juveniles were most often observed perched on the ground in grasslands with <10% sagebrush cover. Juveniles were observed making short flights during the second week. Activity shifted away from the nest site the third week. Juveniles were most often located with siblings. FH-033 was last seen with siblings and

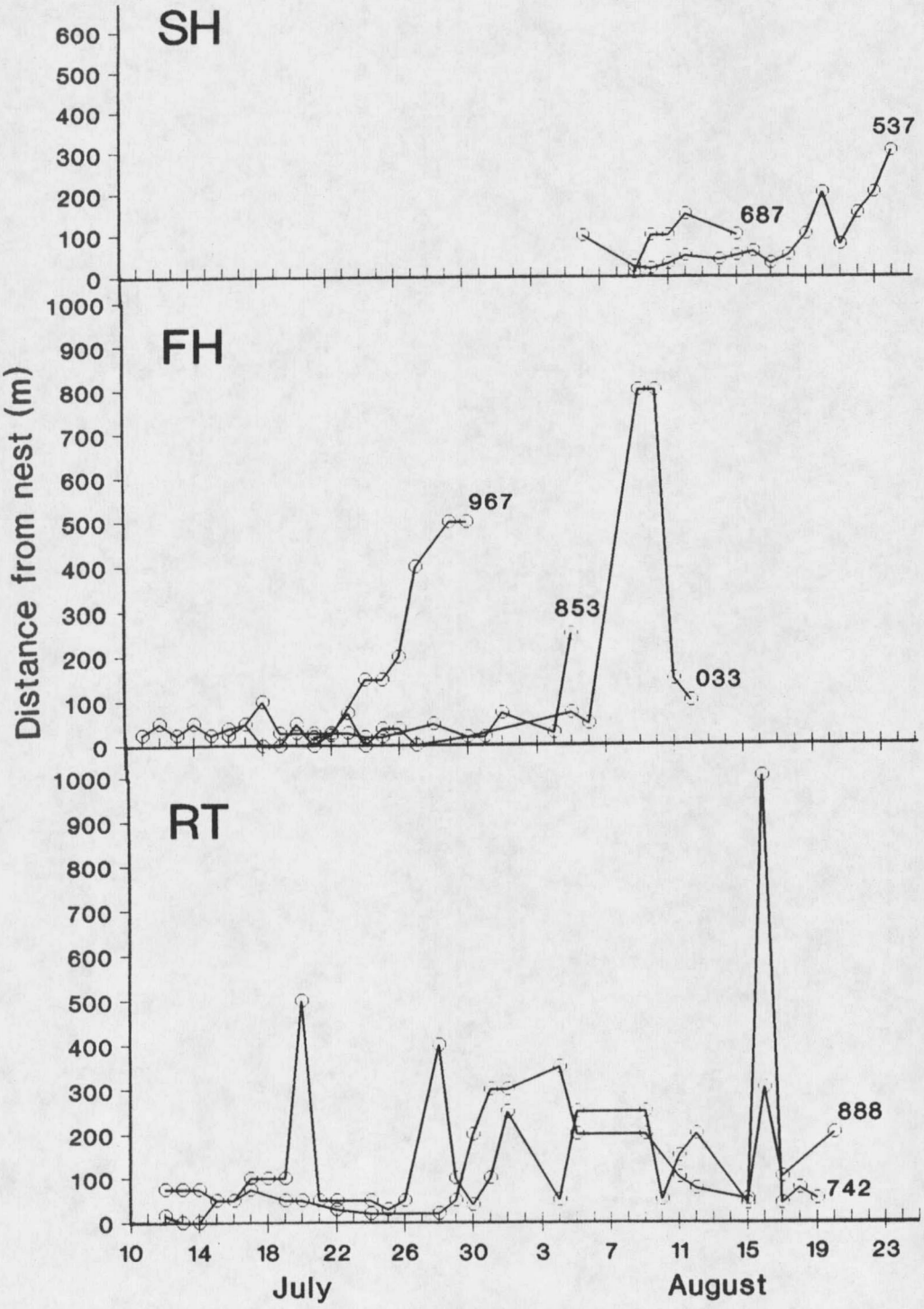


Figure 12. Distance from natal nests per day after fledging of radio-tagged juvenile red-tailed (RT), ferruginous (FH), and Swainson's hawks (SH) on the Centennial Valley study area, Montana, 1988.

parents 26 days after fledging. FH-853 was last observed with parents 19 days after fledging.

SH-537 and SH-687 occupied sparsely vegetated grasslands the first week after fledging. SH-687 was killed 7 days after fledging. Predation by golden eagle was indicated. SH-537 mastered flight the second week and activity shifted to grasslands with 40% sagebrush cover. SH-537 was last seen with its sibling 11 days after fledging but was observed soaring with an adult 4 days later.

Departure of radio-tagged juvenile hawks from the study area was abrupt. RT-742 and RT-888 left on 20 and 21 August, respectively. FH-033 left on 13 August. FH-853 departed the range of its parents on 6 August. It was relocated 15 days later 7 km south of the nest and remained there for 5 days before leaving the study area on 25 August. SH-537 left on 25 August. No radio-tagged juvenile hawk was relocated after departing the study area. One ferruginous hawk banded as a nestling in July 1988 was recovered dead in Los Lunas, New Mexico in March 1989.

In addition to the 2 deaths of radio-tagged juveniles, mortalities of 4 other juveniles were recorded. Two ferruginous hawks were shot 2 days after fledging in 1987. A banded ferruginous hawk was found dead from starvation 31 days after fledging in 1988. A banded Swainson's hawk was killed by a vehicle 7 days after fledging in 1988.

Raptor Community

Seven species of diurnal raptors were regular users of the study area and an additional 8 raptor species were occasionally recorded (Table 18). Eight species were known nesters and 2 species suspected nesters. Five species did not nest on the study area, 3 of which were transients.

Table 18. Raptor community composition (%) on the Centennial Valley study area, Montana, based on 468 observations during 1987 and 1043 observations during 1988.

Species	1987	1988	1987-88	Observed status
Swainson's hawk (*Buteo swainsoni*)	30.3	29.3	29.6	nester
Ferruginous hawk (*Buteo regalis*)	28.0	27.6	27.7	nester
Red-tailed hawk (*Buteo jamaicensis*)	18.8	19.9	19.6	nester
Northern harrier (*Circus cyaneus*)	9.2	8.1	8.5	nester
Prairie falcon (*Falco mexicanus*)	5.1	6.4	6.0	nonnester
American kestrel (*Falco sparverius*)	1.7	4.1	3.4	nester
Golden eagle (*Aquila chrysaetos*)	3.6	2.6	2.9	nester
Peregrine falcon (*Falco peregrinus*)	0.9	0.7	0.7	nester
Long-eared owl (*Asio otus*)	1.7	0.0	0.5	nester
Rough-legged hawk (*Buteo lagopus*)	0.0	0.4	0.3	transient
Short-eared owl (*Asio flammeus*)	0.2	0.4	0.3	nester?
Burrowing owl (*Athene cunicularia*)	0.4	0.1	0.2	nester?
Cooper's hawk (*Accipiter cooperii*)	0.2	0.1	0.1	transient
Sharp-shinned hawk (*Accipiter striatus*)	0.0	0.2	0.1	transient
Bald eagle (*Haliaeetus leucocephalus*)	0.0	0.1	0.1	nonnester

Cooper's (Accipiter cooperii) and sharp-shinned hawks (A. striatus) were recorded during spring migration only. Both species likely nested in forests adjacent to the study area.

Northern harriers (Circus cyaneus) inhabited grass-sagebrush communities. Harriers were most often observed hunting on the valley floor and were rarely seen in foothills.

Rough-legged hawks (B. lagopus) were observed during early spring and remained on the study area until 2 May during 1988. Red-tailed, ferruginous, and Swainson's hawks were the most common and obvious raptors on the study area.

Golden eagles were common on the valley floor. Fifty-two percent of all golden eagles observed for which age could be determined (n=22) were adults. Two of their nests were located on the study area: 1 on a cliff and 1 in a Douglas fir. Observations of bald eagles (Haliaeetus leucocephalus) were of adults only. One bald eagle nest, located 0.7 km south of the study area, was occupied during 1987 and 1988.

During 1988, a pair of peregrine falcons (Falco peregrinus) nested on the study area on an old hack tower. Observations of peregrines were generally confined to the vicinity of the tower. Prairie falcons (F. mexicanus) were the only commonly sighted raptor which did not nest on the study area, but they probably nested on cliffs adjacent to the study area. American kestrels (F. sparverius) nested in aspen and were observed most often perched on power lines.

Long-eared owls (Asio otus) nested in willow thickets along streams. Although rarely seen, repeated observations of pairs of

short-eared (A. flammeus) and burrowing owls (Athene cunicularia) at specific locations suggested that these species nested on the study area.

Interspecific Interactions

Twenty-eight interspecific interactions among red-tailed, ferruginous, and Swainson's hawks were observed (Table 19). Conflicts were evenly distributed from early May to late July. Twenty-one (75%) interactions occurred near active nests. Three conflicts observed in late July involved a combination of adult and juvenile hawks. In each case the juvenile was a red-tailed hawk. Aggressor species were always conflict winners.

Table 19. Number of interspecific interactions and outcome among red-tailed (RT), ferruginous (FH), and Swainson's hawks (SH) on the Centennial Valley study area, Montana, 1987 and 1988.

Hawk species	Number of interactions	Aggressor			Winner		
		RT	FH	SH	RT	FH	SH
RT&FH	3	1	2		1	2	
RT&SH	15	0		15	0		15
FH&SH	10		2	8		2	8

Physical contact between hawks occurred during 8 (29%) interactions. Swainson's hawks repeatedly stooped at red-tailed hawks during 6 fights. The red-tailed hawk repeatedly rolled and presented talons to the oncoming Swainson's hawk during each bout. After brief talon grappling, the red-tailed hawk retreated. Swainson's hawks attacked ferruginous hawks twice in a similar manner.

In an unusual case, an adult male Swainson's hawk stole a ground squirrel from an adult male red-tailed hawk. The male red-tailed hawk made the kill and then walked with the squirrel towards his mate which was perched on a post. The Swainson's hawk flew in, grabbed the squirrel and ate it on the ground in front of the 2 red-tailed hawks before leaving.

Two intraspecific interactions were observed. Two ferruginous hawks were observed tumbling 10 m in the air with talons locked on 10 July 1988. Two Swainson's hawks were observed fighting on 24 July 1988.

Seven interactions involving either ferruginous or Swainson's hawks and other raptors were observed. Swainson's hawks attacked golden eagles 3 times. A prairie falcon and northern harrier were observed stooping Swainson's hawks on separate occasions. Ferruginous hawks and prairie falcons were observed stooping each other on 2 separate occasions.

DISCUSSION

Red-tailed hawks were the least common buteo nesting on the study area with ferruginous hawks intermediate and Swainson's hawks most common. Ferruginous and Swainson's hawks are considered prairie hawks and red-tailed hawks birds of mixed grassland and woodland (Bent 1937, Brown and Amadon 1968). Thurow et al. (1980) felt whenever these 3 buteos were sympatric 1 was always much rarer than the others. However, habitat on my study area supported a more even distribution of buteo numbers, a situation different from other studies (Schmutz et al. 1980, Cottrell 1981).

Most (88%) active nests were located in foothill drainages surrounding the valley floor and distance to nearest neighbor for all species combined and between congeners was significantly less than expected using the technique of Clark and Evans (1954). Newton (1979) stated a shortage of nest substrates existed if nest distribution deviated from regular spacing and if otherwise suitable habitat was occupied only if nest substrates were available. Clumped nest distribution reflected a shortage of nesting habitat which appeared to play a dominant role in overall distribution of nests on my study area. The only elevated nest substrates available were small stands of aspen at drainage heads, willows bordering streams, and scattered Douglas fir. Rock outcrops were rare. The valley floor generally lacked elevated nest substrates and was too flat to provide ground

nesting opportunities for ferruginous hawks as suggested by Fitzner et al. (1977), Blair and Schitoskey (1982), Ensign (1983), and Gilmer and Stewart (1983).

Distance between conspecific nests varied between closer and farther apart than expected, but differences were not significant. However, red-tailed and Swainson's hawks nested significantly farther than expected from conspecifics in Alberta (Rothfels and Lein 1983), and Knight and Smith (1982) found widely spaced nests of red-tailed and ferruginous hawks in Washington. These authors felt their study areas contained a near-optimum distribution and availability of nesting habitat. Poor distribution of nest substrates prohibited greater distance between conspecific nests on the Centennial Valley study area.

Aggregated distribution of nest sites probably increased interspecific interactions by bringing territorial hawk pairs into close proximity. Most (75%) interspecific interactions occurred near active nests. I recorded 3 times the number of aggressive interactions as Schmutz et al. (1980) in Alberta; the Alberta nests were spaced more evenly and farther apart. Poole and Bromley (1988) reported interspecific interactions became more intense as intruders got closer to nests. Interspecific territoriality may be maintained when vegetation structure is simple or when some resource is limiting (Orians and Willson 1964). Evidence suggests that nest sites were limiting and structure of grass-shrub and willow vegetation on the study area was simple. These conditions likely explain the high level of territoriality observed.

Red-tailed and ferruginous hawks established territories first and differences in nest substrate and nest site characteristics were most pronounced between these 2 species. This was in contrast to Cottrell (1981) and MacLaren et al. (1988) who reported no difference in nest site characteristics between these species, but was similar to the findings of Platt (1971), Schmutz et al. (1980), and Knight and Smith (1982).

Superior flight capabilities, suggested by low wing-loading, combined with an aggressive demeanor, enabled Swainson's hawks to establish territories near nesting red-tailed and ferruginous hawks, as in Colorado (Olendorff 1973) and Oregon (Janes 1985, 1987). Swainson's hawks were the most aggressive species and dominated in most (92%) encounters in which they were involved. Swainson's hawks were also the most aggressive species in Alberta (Schmutz et al. 1980).

Aspen stands were occupied exclusively by red-tailed hawks. A few aspen stands remained unoccupied but were not used by either ferruginous or Swainson's hawks. It seems unlikely that red-tailed hawks preferred to nest in trees more than ferruginous and Swainson's hawks because the latter have commonly nested in trees (Cottrell 1981, Gilmer and Stewart 1983, 1984). Aspen clumps were located at high elevation, on steep slopes, and farthest from the valley floor, 3 characteristics which may have made them less desirable to ferruginous and Swainson's hawks. Smith and Murphy (1973) and MacLaren et al. (1988) also reported red-tailed hawks nesting at higher elevations than ferruginous hawks. In general, red-tailed hawks avoided areas of

low relief while Swainson's hawks preferred such sites in Oregon (Janes 1985). Red-tailed hawks nested on steeper slopes when available (Titus and Mosher 1981, Bednarz and Dinsmore 1982, Speiser and Bosakowski 1988).

Willows were the most common nest substrate. Most (71%) ferruginous hawk nests were in willow. Janes (1987) felt willows couldn't support ferruginous hawk nests. This difference is probably explained by shrub structure. Willows in the Centennial Valley were large and thick branched and had a structure much more similar to trees than shrubs.

Ferruginous and Swainson's hawks showed great overlap in nest substrate use, probably due to lack of substrate diversity on the study area. Similar conditions were reported in Utah (Smith and Murphy 1982) and Oregon (Green and Morrison 1983). However, differences in nest and nest site characteristics were noted between ferruginous and Swainson's hawks on the Centennial Valley study area. Exposure of ferruginous hawk nests, reflected in LDE and window size, was much greater than Swainson's hawk nests which were often enclosed with branches. Dunkle (1977) reported similar Swainson's hawk nest placement. Ferruginous hawk nest sites were lower in elevation and in more open stands, the latter also reported by Lokemoen and Duebbert (1976) and Woffinden and Murphy (1983). Willow stands growing along foothill streams ended once adjacent to the Centennial Valley. Ferruginous hawk nests were most often located in the more exposed end willows. Preference for exposed sites has been noted elsewhere (Smith and Murphy 1973, Blair and Schitoskey 1982, Ensign 1983, Gilmer and

Stewart 1983). Ferruginous hawks may have also preferred the shorter distance to foraging areas.

Differences in nest substrate height between ferruginous and Swainson's hawks were reported in Alberta (Schmutz et al. 1980) and Oregon (Cottrell 1981, Green and Morrison 1983). This was not possible to any degree on my study area due to the uniform height of willows.

Nest position and window direction varied widely for each species with no apparent preference or avoidance for any orientation. This suggested that hawk nestlings were not exposed to great thermal stress, as has been observed in golden eagle nestlings (Mosher and White 1976), and therefore was an unimportant consideration in nest site selection. Slope aspect at nests were similar among species and reflected availability of nest substrates and not slope preference. Cottrell (1981) observed partitioning of slope aspect among the 3 buteos and related it to nest substrate availability. Whereas ferruginous hawk ground nests often had distinct aspect orientations (Lokemoen and Duebbert 1976, Gilmer and Stewart 1983), aspect at tree nests varied (Woffinden and Murphy 1983).

Adjustments to compensate for thermal stress associated with south facing slopes could likely be made by altering nest position, but nest position on the study area showed no clear pattern. Bednarz and Dinsmore (1982) and Speiser and Bosakowski (1988) felt red-tailed hawks avoided nesting on southwest facing slopes because of high unfavorable temperatures. High elevation and latitude of the Centennial Valley probably reduced thermal stress.

Human disturbance in the Centennial Valley was minor and probably did not affect nest site selection. This contrasts with results from other studies where raptors were found to nest farther than expected from roads and buildings (Lokemoen and Duebbert 1976, Knight and Smith 1982, and MacLaren et al. 1988). The study area was remote and used only for summer cattle grazing, an activity compatible with ferruginous hawk persistence (Schmutz 1987). Ferruginous hawks nested closest to roads and buildings, areas associated with high LDE. This suggests that man and his artifacts didn't necessarily cause disturbance or were at levels below threshold. Ferruginous hawks apparently habituate to some forms of low level disturbance (White and Thurow 1985).

Nesting chronologies of red-tailed and ferruginous hawks overlapped most while Swainson's hawks nested 3 weeks later. Staggered breeding cycles of these buteos have been reported elsewhere (Platt 1971, Smith and Murphy 1973, Schmutz et al. 1980, Cottrell 1981). Staggered breeding cycles could not reduce possible interspecific competition for nest substrates because sites were occupied all summer. Staggered cycles probably did not reduce possible competition for food because of the large overlap of nestling periods from late June to mid-July, the period when food demand was highest. Cody (1974) felt that interspecific displacement of breeding seasons in temperate bird communities was negligible and not a factor in community organization. Staggered breeding cycles likely reflect the much longer migration of Swainson's hawks compared to the migrations of red-tailed and ferruginous hawks.

Hawk productivity was similar to that reported in Montana (Seidensticker and Reynolds 1971, Johnson 1975, Myers unpublished data) and elsewhere (Dunkle 1977, Schmutz et al. 1980, Cottrell 1981, Gilmer and Stewart 1983, 1984). Human disturbance has significantly reduced productivity in some areas (Wiley 1975, Craighead and Mindell 1981, White and Thurow 1985), but on my study area presence of roads, buildings, and grazing did not significantly affect productivity or success of nests. This probably reflected the low level of disturbance and hawk tolerance.

Reduced productivity in buteos has been reported in nests spaced less than 0.3 km apart (Schmutz et al. 1980) and in nests in view of other nests (Cottrell 1981). Neither of these factors significantly decreased productivity on my study area despite the high level of territoriality observed. However, productivity did decrease somewhat and lack of statistical significance may have been affected by small sample sizes. Poole and Bromley (1988) also reported no difference and suggested that other factors such as weather may have had a greater effect on reproductive success.

Productivity was higher during 1988, a severe drought year, than during 1987. Cottrell (1981) also reported increased productivity during a drier year and related it to prey availability; ground squirrels were more active above ground during drier weather. In the high altitude Centennial Valley, spring snowstorms probably acted directly on hawk reproductive success by killing developing embryos or small nestlings. The severe hailstorm on 22 June 1987 may have caused nest failures, particularly of the later nesting Swainson's hawks.

Wet weather conditions have reduced raptor productivity elsewhere (Fitch et al. 1946, Olendorff 1973, Adamcik et al. 1979, Gilmer and Stewart 1983).

Swainson's hawks had the largest niche breadth of prey with red-tailed hawks intermediate and ferruginous hawks smallest. Swainson's hawks took twice as many bird species as the other 2 hawk species. Bednarz (1988) considered Swainson's hawks very opportunistic when foraging. Ferruginous hawks are predominantly mammal hunters (Brown and Amadon 1968). Niche breadth relationships were similar to those observed in Utah (Jaksic and Braker 1983, using Smith and Murphy 1973 data) and in southeastern Idaho (Steenhof and Kochert 1985). Diversity of items in diets across regions likely reflect local prey abundance and availability (Jaksic and Braker 1983).

Dietary overlap exceeded 85% in each pairwise combination with highest overlap between red-tailed and ferruginous hawks and lowest overlap between ferruginous and Swainson's hawks. A similar relationship occurred in Utah (Jaksic and Braker 1983, using Smith and Murphy 1973 data). Extremely high (99%) dietary overlap between red-tailed and ferruginous hawks was observed in Wyoming (MacLaren et al. 1988). Thurow and White (1983) reported low (52%) dietary overlap between ferruginous and Swainson's hawks in Oregon.

High dietary overlap does not imply intense competition because prey may be abundant and not limiting (Lack 1946, Lawlor 1980). Prey abundance may affect raptor productivity (Smith and Murphy 1973, Adamcik et al. 1979, Newton 1979). Because productivity on my study area was similar to that on other areas and prey appeared to be

abundant, it seemed unlikely that food was a limiting resource. Schmutz et al. (1980) reached the same conclusion in Alberta. Lack of breeding sites have kept raptor populations below levels where competition for prey might occur (Lack 1946, Wiens 1977). This probably was the situation on my study area. In southeastern Idaho, interspecific competition did not affect diet composition of red-tailed and ferruginous hawks (Steenhof and Kochert 1985).

Although dietary overlap was great, birds could forage in different habitats, use different methods, or hunt at different times and take prey not available to the other species (Lack 1971, Cody 1974). There appeared to be no partitioning of hawk hunting habitat on the study area. Different buteo species often hunted simultaneously over common ground. Hawks hunted mainly over the valley floor, an area of relatively uniform grassland with little brush cover in which prey appeared to be readily available. Vegetative cover has been reported to be more important than prey density in determining preferred foraging ground (Luttich et al. 1970, Orde and Harrel 1977, Wakely 1978, Bechard 1982, Bednarz 1988) .

Hawks used different hunting techniques. However, Schmutz et al. (1980) found no evidence to suggest that hawks took different segments of the prey population due to this behavior.

Foraging activity was intense mid-morning when ground squirrels were most active. A lull in hawk and ground squirrel activity occurred mid-day when temperatures were highest. Ground squirrels resurfaced and hawk activity increased in late afternoon when temperatures dropped. Similar activity patterns and lack of different

hawk foraging times was also reported in Alberta (Schmutz et al. 1980).

Time of activity as a niche difference was not important regarding exploitation competition (Schoener 1974). However, Case and Gilpin (1974) and Carothers and Jaksic (1984) argued time was an important niche axis during interference competition. Because prey did not appear to be limiting, exploitation competition probably was not occurring. Most (75%) interspecific interactions occurred near nests. Lack of interference competition at hawk foraging areas probably reduced the need for temporal partitioning of foraging activity.

The main prey for each hawk species on the study area was ground squirrels, as in Alberta (Schmutz et al. 1980), Oregon (Cottrell 1981), Wyoming (MacLaren et al. 1988), and Idaho (Steenhof and Kochert 1985). However, prey partitioning was observed on my study area and likely reflected prey availability and hawk natural history characteristics. Swainson's hawks took more birds and voles but fewer ground squirrels than red-tailed and ferruginous hawks. Ground squirrels estivated in mid-July and became less available to the later nesting Swainson's hawks while at the same time young passerines were beginning to fledge. Swainson's hawks took more birds than red-tailed and ferruginous hawks on the Idaho-Utah border (Thurow et al. 1980) and in Utah (Smith and Murphy 1973). Schmutz et al. (1980) reported that although Swainson's and ferruginous hawks took avian orders in different proportions, little reduction in potential competition occurred because avian prey contributed little to diet biomass.

Juvenile radio-tagged hawks did not appear to partition habitat use. Instead habitats near nests were used in proportion to their availability. Although juveniles fledged on different dates, each dispersed approximately the third week of August, which may have coincided with a drop in prey availability as young passerines developed flight during this time and ground squirrels were largely below ground. A drop in adult numbers was also noted at this time. Length of post-fledging periods resembled those reported by Johnson (1973), Woffinden and Murphy (1983), and Konrad and Gilmer (1986). No radio-tagged hawks congregated at the fall raptor concentration at Henry's Lake, Idaho.

In summary, the buteo hawks partitioned habitat resources, specifically nest sites. Red-tailed and ferruginous hawks, the 2 species with the greatest overlap in nesting chronology and prey utilization, had the least nest substrate overlap. Swainson's and ferruginous hawks, the 2 species with the greatest nest substrate overlap, had the lowest dietary overlap observed. Although these 2 species utilized willows extensively, significant differences in site characteristics were noted. Prey did not appear to be a limiting resource and diet differences observed probably reflected prey availability and not active partitioning. There was no strong evidence to suggest partitioning of foraging activity.

MANAGEMENT RECOMMENDATIONS

The Bureau of Land Management (BLM) identified the Centennial Valley of Montana as a "Key Raptor Area" (Olendorff et al. 1989). It is 1 of the few areas in the state where ferruginous hawks, a species of special concern in Montana (Harlow and Bloom 1987), commonly nest. Because this species is particularly sensitive to human disturbance (Fyfe and Olendorff 1976), associated with relatively undisturbed grasslands (Brown and Amadon 1968, Schmutz 1987), and very visible, it would be a useful indicator of buteo population trends and habitat quality. Red-tailed hawks are increasing and Swainson's hawks stable in Montana (Harlow and Bloom 1987), and therefore would be less useful as indicators.

Population trends cannot be determined from this short-term study. However, 2 characteristics can be inferred from the data: (1) nest substrates appeared to be limiting, indicating saturated habitat and (2) productivity of each species compared well with that reported from other studies, indicating good reproduction.

Raptor populations should be monitored at least every 5 years in key areas (Olendorff et al. 1989). Road surveys conducted in early spring, before leaf out, could determine the occupancy of at least 8 ferruginous hawk sites. Nests should only be observed from the road with spotting scopes and binoculars. Road surveys used to determine relative raptor community composition are biased and should only be

used as a rough index to determine population trends of target species. Call (1978) described raptor survey techniques in detail and provided helpful suggestions.

If desirable, intensive nest searches could be carried out in suitable habitat such as willow bordered streams and aspen clumps. However, searches should not be conducted until after incubation periods (mid-June for red-tailed and ferruginous hawks and early July for Swainson's hawks) to reduce the potential for nest abandonment (Fyfe and Olendorff 1976, Call 1979).

Habitat of key areas should also be monitored at least every 5 years (Olendorff et al. 1989). Although most of the range on private and public land was in good to fair condition, overgrazing presents a short-term threat to buteo populations. Overgrazing can (1) reduce nest substrate availability (Call 1978, Kochert 1987), (2) potentially reduce prey diversity and abundance (Kochert 1987), and (3) change vegetation composition, structure, and diversity (Call 1979).

Seventy-five (87%) nests were found in riparian areas, most of which were moderately grazed. Willow stands in grazed areas were severely rubbed, decadent, and lacked regeneration. If willow vigor declines, these areas should be protected by changing grazing regimes and/or fencing (Olendorff and Stoddart 1974). As a last resort, artificial nest structures could be employed; this practice has been successful elsewhere (Howard and Hilliard 1980, Schmutz et al. 1984).

Prey was not a limiting resource, but severe overgrazing has reduced prey abundance in other areas (Kochert 1987). Problems

associated with overgrazing will probably be reflected in nest substrate decline first. Moderate grazing reduced overhead cover and thus made prey more vulnerable. In general, grazing activity is compatible with ferruginous hawk persistence.

Because the Centennial Valley is remote, human disturbance was low and not a current management concern. Landowners were either indifferent to hawks or very interested in their welfare. However, human disturbance may become a long term problem. Increased development around Henry's Lake, Idaho approximately 60 km to the east has resulted in more people visiting the Centennial Valley.

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APPENDIX

Table 20. Mammalian species observed on the Centennial Valley study area, Montana, 1987 and 1988.

Common name	Scientific name
Masked shrew	Sorex cinereus
Little brown bat	Myotis lucifugus
Long-tailed weasel	Mustela frenata
Mink	Mustela vison
Badger	Taxidea taxus
Striped skunk	Mephitis mephitis
Coyote	Canis latrans
Red fox	Vulpes vulpes
Yellow-bellied marmot	Marmota flaviventris
Uinta ground squirrel	Spermophilus armatus
Wyoming ground squirrel	Spermophilus elegans
Least chipmunk	Eutamias minimus
Red squirrel	Tamiascurus hudsonicus
Northern pocket gopher	Thomomys talpoides
Beaver	Castor canadensis
Deer mouse	Peromyscus maniculatus
Meadow vole	Microtus pennsylvanicus
Sagebrush vole	Lagurus curtatus
White-tailed jackrabbit	Lepus townsendii
Elk	Cervus elaphus
Mule deer	Odocoileus hemionus
White-tailed deer	Odocoileus virginianus
Moose	Alces alces
Pronghorn	Antilocapra americana

Table 21. Avian species observed on the Centennial Valley study area, Montana, 1987 and 1988.

Common name	Scientific name
Common loon	Gavia immer
Pied-billed grebe	Podilymbus podiceps
Eared grebe	Podiceps nigricollis
Western grebe	Aechmophorus occidentalis
American white pelican	Pelecanus erythrorhynchos
Double-crested cormorant	Phalacrocorax auritus
Great blue heron	Ardea herodias
White-faced ibis	Plegadis chihi
Trumpeter swan	Cygnus buccinator
Canada goose	Branta canadensis
Wood duck	Aix sponsa
Green-winged teal	Anas crecca
Mallard	Anas platyrhynchos
Northern pintail	Anas acuta
Blue-winged teal	Anas discors
Cinnamon teal	Anas cyanoptera
Northern shoveler	Anas clypeata
Gadwall	Anas strepera
American widgeon	Anas americana
Lesser scaup	Aythya affinis
Common merganser	Mergus merganser
Turkey vulture	Cathartes aura
Bald eagle	Haliaeetus leucophalus
Northern harrier	Circus cyaneus
Sharp-shinned hawk	Accipiter striatus
Swainson's hawk	Buteo swainsoni
Red-tailed hawk	Buteo jamaicensis
Ferruginous hawk	Buteo regalis
Rough-legged hawk	Buteo lagopus
Golden eagle	Aquila chrysaetos
American kestrel	Falco sparverius
Peregrine falcon	Falco peregrinus
Prairie falcon	Falco mexicanus
Gray partridge	Perdix perdix
Blue grouse	Dendragapus obscurus
Sage grouse	Centrocercus urophasianus
Sora	Porzana carolina
American coot	Fulica americana
Sandhill crane	Grus canadensis
Killdeer	Charadrius vociferus
American avocet	Recurvirustra americana
Solitary sandpiper	Tringa solitaria
Willet	Catoptrophorus semipalmatus
Spotted sandpiper	Actitis macularia
Long-billed curlew	Numenius americanus
Wilson's phalarope	Phalaropus tricolor

Table 21. Continued.

Common name	Scientific name
Franklin's gull	Larus pipixcan
California gull	Larus californicus
Rock dove	Columba livia
Mourning dove	Zenaida macroura
Great horned owl	Bubo virginianus
Burrowing owl	Athene cunicularia
Long-eared owl	Asio otus
Short-eared owl	Asio flammeus
Common nighthawk	Chordeiles minor
Belted kingfisher	Ceryle alcyon
Yellow-bellied sapsucker	Sphyrapicus varius
Northern flicker	Colaptes auratus
Western kingbird	Tyrannus verticalis
Eastern kingbird	Tyrannus tyrannus
Horned lark	Eremophila alpestris
Tree swallow	Tachycineta bicolor
Cliff swallow	Hirundo pyrrhonota
Barn swallow	Hirundo rustica
Clark's nutcracker	Nucifraga columbiana
Black-billed magpie	Pica pica
American crow	Corvus brachyrhynchos
Common raven	Corvus corax
Mountain chickadee	Parus gambeli
Rock wren	Salpinctes obsoletus
House wren	Troglodytes aedon
Ruby-crowned kinglet	Regulus calendula
Mountain bluebird	Sialia currocoides
American robin	Turdus migratorius
Sage thrasher	Oreoscoptes montanus
Loggerhead shrike	Lanius ludovicianus
European starling	Sturnus vulgaris
Solitary vireo	Vireo solitarius
Warbling vireo	Vireo gilvus
Yellow warbler	Dendroica petechia
Yellow-rumped warbler	Dendroica coronata
MacGillivray's warbler	Oporornis tolmiei
Western tanager	Piranga ludoviciana
Lazuli bunting	Passerina amoena
Chipping sparrow	Spizella passerina
Brewer's sparrow	Spizella breweri
Vesper sparrow	Pooecetes gramineus
Lark bunting	Calamospiza melanocorys
Savannah sparrow	Passerculus sandwichensis
Song sparrow	Melospiza melodia
White-crowned sparrow	Zonotrichia leucophyrs
Dark-eyed junco	Junco hyemalis
Red-winged blackbird	Agelaius phoeniceus

Table 21. Continued.

Common name	Scientific name
Western meadowlark	Sturnella neglecta
Yellow-headed blackbird	Xanthocephalus xanthocephalus
Brewer's blackbird	Euphagus cyanocephalus
Brown-headed cowbird	Molothrus ater

Table 22. Substrates of red-tailed, ferruginous, and Swainson's hawk nests on the Centennial Valley study area, Montana, 1987 and 1988.

Hawk species	Ground		Willow		Aspen		Douglas fir		Power pole	
	1987	1988	1987	1988	1987	1988	1987	1988	1987	1988
Red-tailed	0	0	2	2	7	6	2	1	0	0
Ferruginous	2	1	10	7	0	0	1	2	0	1
Swainson's	0	0	21	20	0	0	0	1	0	0
Total	2	1	33	29	7	6	3	4	0	1

Table 23. Characteristics of nest substrates of red-tailed, ferruginous, and Swainson's hawks on the Centennial Valley study area, Montana, 1987 and 1988.

Hawk species	Height (m)				DBH (cm)[a]		Decadence (%)				Shortest dist. to stand edge(m)			
	1987		1988		1987	1988	1987		1988		1987		1988	
	Mean	SD	Mean	SD	Mean	Mean	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Red-tailed	13.9	5.3	13.9	6.5	32	35	12	15	15	17	11	8	12	11
Ferruginous	5.0	1.9	5.5	2.7		26	28	27	33	33	4	4	3	3
Swainson's	5.1	1.2	5.1	1.2			28	27	20	26	3	2	4	3

[a] Diameter at breast height.

Table 24. Characteristics of nests of red-tailed, ferruginous, and Swainson's hawks on the Centennial Valley study area, Montana, 1987 and 1988.

Hawk species	Height (m)				Window size (°)				LDE (°)[a]			
	1987		1988		1987		1988		1987		1988	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Red-tailed	8.8	3.4	9.1	3.8	48	28	48	27	22	30	24	28
Ferruginous	3.7	1.6	4.1	2.7	113	115	137	112	68	49	68	50
Swainson's	3.7	1.0	3.9	1.2	29	15	49	30	10	15	18	27

[a] Long distance exposure.

Table 25. Dimensions of red-tailed, ferruginous, and Swainson's hawk nests on the Centennial Valley study area, Montana, 1987 and 1988.

Hawk species	Dimensions (LXW) (cm)[a]							
	Nest		Bowl		Nest		Bowl	
	1987				1988			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Red-tailed	87X66	19X22	53X34	15X11	84X64	18X16	33X30	8X7
Ferruginous	130X103	28X32	57X44	15X7	123X92	24X26	58X46	18X4
Swainson's	77X62	17X14	39X32	7X6	81X66	12X10	40X34	6X7

[a] Length X width.

Table 26. Characteristics of nest sites of red-tailed, ferruginous, and Swainson's hawks on the Centennial Valley study area, Montana, 1987 and 1988.

Hawk species	Slope (%)				Elevation (m)				Stand Density (trees/ha)				Stand Height (m)			
	1987		1988		1987		1988		1987		1988		1987		1988	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Red-tailed	11	9	10	8	2,120	65	2,131	67	659	466	572	300	7.5	3.0	7.1	3.6
Ferruginous	9	10	12	11	2,079	39	2,070	31	314	268	396	470	3.5	2.0	4.4	2.6
Swainson's	7	4	8	8	2,100	51	2,110	55	685	586	604	529	3.8	0.9	3.9	0.8

Table 27. Vegetation composition (%) around nests of red-tailed, ferruginous, and Swainson's hawks on the Centennial Valley study area, Montana, 1987 and 1988.

Hawk species	Aspen				Willow				Sagebrush				Grass/forb			
	1987		1988		1987		1988		1987		1988		1987		1988	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Red-tailed	20	20	16	17	10	12	13	14	24	12	19	11	45	11	52	19
Ferruginous	0	0	0	0	8	7	11	6	25	16	17	15	67	16	72	12
Swainson's	0	1	0	1	14	6	11	6	23	16	20	15	64	16	69	14

Table 28. Morphological characteristics of red-tailed, ferruginous, and Swainson's hawks radio-tagged on the Centennial Valley study area, Montana, 1988.

Characteristic[a]	Hawk				
	RT-776	RT-832	FH-412	FH-825	SH-253
Band number	180701079	138720908	138720904	120742291	138720905
Culmen	31.9	24.6	27.9	31.1	24.1
Bill depth	18.1	17.3	18.4	20.9	15.5
Gape	45.0	43.2	53.4	57.5	40.0
Eye diameter	1.6	1.6	1.6	1.9	1.6
Wing chord (flat)	40.3	39.5	44.1	44.1	40.5
Wing chord (curved)	40.0	38.9	43.8	42.9	39.4
Wing span	128.2	129.6	143.1	144.8	123.8
8th primary length	29.4	27.0	32.7	29.5	39.1
Tail length	21.3	21.0	22.2	23.2	20.6
Tarsal width (AP)[b]	12.0	10.5	10.4	14.0	10.2
Tarsal width (lat)[b]	8.8	8.5	8.1	11.9	7.6
Foot pad length	68.6	62.1	72.6	70.5	66.1
Hallux claw length	30.6	28.2	21.3	31.3	24.8
Girth	35.2	30.6	28.9	39.1	26.4
Weight (g)	1150.0	925.0	1225.0	1850.0[c]	875.0
Wing loading (g/cm^2)	1.1	0.8	1.0	1.5	0.8

[a] All measurements in cm unless otherwise indicated.
[b] Anterior/posterior and lateral.
[c] Captured with a full crop.

Table 29. Morphological characteristics of juvenile red-tailed, ferruginous, and Swainson's hawks radio-tagged on the Centennial Valley study area, Montana, 1988.

Juvenile	Band number	Culmen	Bill depth	Tarsal width[a]		Hallux claw length
				AP	Lat	
RT-742	87775678	20.9	15.9	11.8	7.5	25.2
RT-888	87775681	21.2	16.0	11.4	8.9	26.0
FH-033	87775676	21.9	14.7	10.6	8.6	24.9
FH-853	120742296	25.0	12.7	13.0	11.4	29.0
FH-967	87775675	21.0	15.3	9.7	7.6	23.9
SH-537	81687782	19.5	13.5	8.7	6.6	22.2
SH-687	180701076	22.0	15.8	10.1	7.4	23.1

[a] Anterior/posterior and lateral.

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