ABSTRACT

Birds of prey (raptors) occupy the top position in several food chains. Contaminants such as pesticides accumulate in the bodies of these birds at a level ten times greater than found in their prey, and can cause reproductive failures or mortality among adults. The same may be true of accumulations of heavy metals.

The broad-winged hawk and kestrel (sparrow hawk) are probably the most numerous raptors on the RCNSA. Broad-wing habitat, primarily aspen-birch uplands, is distributed throughout the eastern one-third of the Study Area where raptor observations were concentrated. Kestrels occupy recently cleared land and shrub communities, habitats somewhat limited in this predominantly forested region.

Other raptors with relatively high densities are red-tailed hawks, great horned owls and barred owls. Raptors with large territories and/or generally low densities include goshawks and Cooper's hawks. The distribution of marsh hawks is probably limited by the scarcity of grass-sedge marshes and open grassy fields. Other raptors which are known to breed on the RCNSA but are very difficult to observe and/or occur at low densities are the sharp-shinned hawk, long-eared owls, short-eared owl, and saw-whet owl.

The principal prey for larger raptors such as the broad-winged hawk, red-tailed hawk, goshawk and great horned owl are snowshoe hare, followed by ruffed grouse. The remainder of the species concentrate on small mammals

as prey, with Cooper's and sharp-shinned hawks taking primarily song birds. Other lesser prey include waterfowl, spruce grouse, amphibeans, reptiles and insects.

Deciduous and deciduous-coniferous uplands are favorite nesting habitats. These types are dominated by aspen, with paper birch, pines, fir and spruce also important tree species. Of the conifer types, upland red and jack pine are preferred, with generally low nesting densities in lowland spruce forest. We estimate that each km^2 of lowland habitat (spruce-fir-tamarack, unproductive forest, shrub and bog swamp, etc.) lost to mining operations represents the potential loss of nesting and/or feeding habitat for 0.50 pair of raptors. Loss of upland types (aspen, aspen-birch, deciduous-coniferous stands, conifers, shrub communities, etc.) would be more detrimental, with each km^2 of land lost equivalent to habitat for 1.00 pair of raptors.

INTRODUCTION TO THE REGIONAL COPPER-NICKEL STUDY

The Regional Copper-Nickel Environmental Impact Study is a comprehensive examination of the potential cumulative environmental, social, and economic impacts of copper-nickel mineral development in northeastern Minnesota. This study is being conducted for the Minnesota Legislature and state Executive Branch agencies, under the direction of the Minnesota Environmental Quality Board (MEQB) and with the funding, review, and concurrence of the Legislative Commission on Minnesota Resources.

A region along the surface contact of the Duluth Complex in St. Louis and Lake counties in northeastern Minnesota contains a major domestic resource of copper-nickel sulfide mineralization. This region has been explored by several mineral resource development companies for more than twenty years, and recently two firms, AMAX and International Nickel Company, have considered commercial operations. These exploration and mine planning activities indicate the potential establishment of a new mining and processing industry in Minnesota. In addition, these activities indicate the need for a comprehensive environmental, social, and economic analysis by the state in order to consider the cumulative regional implications of this new industry and to provide adequate information for future state policy review and development. In January, 1976, the MEQB organized and initiated the Regional Copper-Nickel Study.

The major objectives of the Regional Copper-Nickel Study are: 1) to characterize the region in its pre-copper-nickel development state; 2) to identify and describe the probable technologies which may be used to exploit the mineral resource and to convert it into salable commodities; 3) to identify and assess the impacts of primary copper-nickel development and secondary regional growth; 4) to conceptualize alternative degrees of regional copper-nickel development; and 5) to assess the cumulative environmental, social, and economic impacts of such hypothetical developments. The Regional Study is a scientific information gathering and analysis effort and will not present subjective social judgements on whether, where, when, or how copper-nickel development should or should not proceed. In addition, the Study will not make or propose state policy pertaining to copper-nickel development.

The Minnesota Environmental Quality Board is a state agency responsible for the implementation of the Minnesota Environmental Policy Act and promotes cooperation between state agencies on environmental matters. The Regional Copper-Nickel Study is an ad hoc effort of the MEQB and future regulatory and site specific environmental impact studies will most likely be the responsibility of the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency.

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INTRODUCTION

Birds of prey (raptors) occupy the top position in several food chains. Their sharply hooked beaks and powerful talons are an important adaptation for grasping such prey or small mammals and songbirds. Recently, however, occupying the top trophic level has proved hazardous for many avian predators. Researchers have demonstrated that pesticides accumulate by a factor of at least 10 with each successive increase in trophic level in a food chain (Sherburne and Diamond 1969, Diamond and Sherburne 1969). The same may also be true of heavy metals. Numerous papers have shown or strongly suggest that the principal effect of pollutants on raptors is a reduction or complete failure in reproduction (Hickey, et al. 1966,;Hickey 1969; Berger, et al. 1970; Enduson and Berger 1968; Lincer, et al. 1970; Cade, et al. 1971; Temple 1972; Keith, et al. 1971; and Synder, et al. 1973).

Although important in the population decline of several species (e.g., peregrine falcon, Falco peregrinus and osprey, Pandion haliaetus), environmental pollutants cannot fully account for the sharp declines that have been observed in other raptor populations, such as that of the Cooper's hawk (Accipiter Cooperii) and sharp-shinned hawk (Accipiter striatus). The loss of valuable habitat has also become an increasing concern. Any future large-scale decrease in raptor habitat should be reviewed seriously. The importance of managing public domain to include raptors has been spelled out in a recent United States Department of Interior (USDI), Bureau of Land Management (BLM) publication (1975):

> "The most prudent and inexpensive methods to brighten the future of birds of prey and their habits is to protect and maintain the key habitat that remains and this includes more

> than just the pristine habitats. This is not to say that all of man's developments have been bad for birds of prey. Certainly, they have not. In addition, many that are bad can be rectified with relatively little effort ... just by considering the biological needs of raptors. ... The key to saving unique areas is governmental ownership by land purchase or exchange of land to acquire these areas. This has been done for the large number and high density of birds using the Snake River Birds of Prey Natural Area, eagle roosting areas, and many others."

A timely example of how some governmental agencies are dealing with potential habitat loss was recently seen in Alaska. The BLM (USDI, 1975) stated that "The site for one of the twelve pumping stations for the Trans-Alaskan Pipeline was relocated to protect nest sites for rough-legged hawks (Buteo lagopus), gyrfalcons (Falco rusticolus), and artic peregrine falcons (Falco peregrinus tundrus).

The recently-observed changes in raptor populations are particularly important in light of their historical stability. In general, forest-inhabiting raptors in the temperate regions have a diversified prey base and maintain relatively stable nesting densities from year to year. The distribution of diurnal raptors (hawks, falcons, accipiters and eagles) "... can be explained largely in terms of two major resources, food and nest sites" (Newton 1976; P294). Newton concluded that most of these species throughout the world are solitary nesters that have exclusive or partly exclusive home ranges. He presented the following four reasons as proof of the relative stability of populations of these species (P278):

1. "their solitary numbers and distribution over many years;
2. the existence of surplus birds, which try to nest when a territory is made available through death of an occupant, but otherwise do not;

3. the re-establishment, after removal by man, of a population showing roughly the same size and distribution as its predecessor on the same ground; and
4. in areas where nest sites are not restricted, a regular spacing of breeding pairs."

Because of the relative stability of breeding populations of forest-inhabiting raptors, the group is especially important as an environmental indicator during long-term monitoring programs. Their susceptibility to certain environmental pollutants further serves as a valuable indicator and lends additional support to the significance of characterizing and monitoring raptor distribution and abundance in environmental studies.

METHODS

The Regional Copper-Nickel Study did not conduct a systematic field project for raptors. Funding was inadequate to undertake the intensive aerial and ground searches required to locate and identify active nesting sites on the Minesite area (term applied to a 1400 km^2 area by the Minnesota Department of Natural Resources (MDNR)). Even if portions of this area were censused, blocks of 40 to 75 mi^2 (100-190 km^2) are customarily sampled over three to five years to determine a range of nesting densities. A study of this magnitude was outside the limits of the current study.

The major emphasis of this paper has been to review and report on scientific papers pertaining to raptor habitat use, food habits, and nesting densities. Studies from northern forested regions have been emphasized. This information is complemented by field data on the frequency of raptors

observed during two field seasons. Applying these findings to specific cover types will allow the resource manager to calculate the probable loss of nesting pairs of raptors in this northern Minnesota region.

The following report does not cover the bald eagle (Haliaeetus leucocephalus) or osprey. These species are considered in detail in separate papers (Copper-Nickel Report No. ,). Field observations of these two species have been included at this time for a comparison of relative abundance.

RESULTS

Raptors Present on the Copper-Nickel Study Area--A General Overview

Approximately 200 field observations of 15 different raptor species were reported by members of the terrestrial portion of the Copper-Nickel Study (Table 1). Only raptors observed within the Minesite area were recorded, with the exception of several sitings of bald eagles, ospreys and one prairie falcon (Falco mexicaus) from within the larger RCNSA (5000 km^2). The most commonly observed raptors were the broad-winged hawk (Buteo platypterus) and the American kestrel (sparrow hawk, Falco sparverius, Table 1). Together these two species represented 67.2 percent of all raptor observations (26.6 and 40.6 percent, respectively). The third most commonly observed was the red-tailed hawk (Buteo jamaicensis), representing 11.4 percent of all observations. Along with the marsh hawk (Circus cyaneus), the kestrel and red-tailed hawk are considered to be the most common breeding raptors in Minnesota (Green and Janssen 1975).

The random observation data presented in Table 1 can have serious limitations. Diurnal hawks (the kestrel, broad-winged, red-tailed, and marsh hawks) have somewhat similar behavioral characteristics that facilitate field observations. These species either nest, perch, soar, or hunt at least part of the day in open or moderately open habitats. As a result, the relative frequency of their observations can be considered representative of their relative abundance on our study area. By contrast, the three accipiters (goshawk, Accipiter gentilis, sharp-shinned hawk and Cooper's hawk) are much more secretive forest species. Meng (1959) has stated that "Accipiters are exceedingly wary, woods hawks and are seldom seen even in areas where they are abundant." This is also attested by the scarcity of detailed density information

for these species in the literature. Casual observation data, such as that presented in Table 1, does not adequately represent the importance of these raptors in the RCNSA.

The largely nocturnal owls pose an even greater observability bias. Only three positive visual records of great-horned owls (Bubo virginianus) and six of barred owls (Strix varia) were made during the study (Table 1). A number of other owl sitings were not included because positive identification was not possible.

Account of Individual Species

BROAD-WINGED HAWK (Buteo platypterus)

Occurrence in the State and General Status

The broad-winged hawk is probably the most numerous raptor in the RCNSA. Breeding throughout forested regions of Minnesota,this hawk is considered

most common in the northern portion of the state (Green and Janssen 1975). Spring migration north from their wintering grounds in Central and South America (Bent 1937) occurs primarily during April, with fall migration occurring mainly during September. The spectacular fall migration of broad-wings at Hawk Ridge in Duluth, Minnesota, illustrates the importance of this raptor in the northern forests of North America. During the past 26 years, 69.3 percent (446,799/644,850) of all observations at this location were of broad-wings (Green, unpublished; see Cu-Ni Report #).

In contrast to the declines recorded in several other hawk species (Snyder, et al. 1973), broad-winged hawk numbers have remained relatively stable (Spofford 1969). This trend is also apparent from the Hawk Ridge data.

Breeding Habitat

Broad-winged hawks nest primarily in upland deciduous forests. Data from New York state (Matray 1974) illustrate a preference for mixed deciduous forests containing 70 percent hardwoods and 30 percent conifers. Nests in Minnesota and Wisconsin were most often located in oak-aspen-birch forests at least 35 years of age (Keran 1976). Nesting sites in Alberta, Canada were dominated by deciduous species, mostly trembling aspen (Populus tremuloidis) and balsam popular (Populus balsamifera ; Rusch, et al. 1972).

Trees used for nesting are generally mature. Keran (1976) found that 29 nest trees ranged from 35 to 50 years in age. Although species may vary with geographic locality, trees usually possess a crotch or branching arrangement where the nest can be securely placed. Preferred nesting

trees in northern Wisconsin were yellow birch (Betula lutea), big-toothed aspen (Populus grandidentata) and trembling aspen (Zirrer 1947); conifers were seldom used. Kerans (1976) found that oaks (Quercus spp.) were preferred as nest trees in the oak-dominated forest in central Minnesota. Aspen and paper birch (Betula papyrifera) were the next most preferred.

It follows from these studies that mid- to old-aged stands of trembling aspen, aspen-paper birch, and mixed coniferous-deciduous forests are probably preferred nesting habitats on our Study Area. This trend is also apparent from our observations where habitat data was also recorded. One of the 25 sites was classified as a recent clearcut, two were pole jack pine (Pinus banksiana) stands, and the remaining 22 were pole or saw classes of aspen, birch, or mixed deciduous forest.

The overall needs of nesting pairs is most successfully met in deciduous forests which have small man-made or natural openings. Keran (1976) reviewed a number of studies and concluded that most findings were very similar to his own:

> "Burns (1911) stated that the ideal area in Pennsylvania for broad-winged hawks consisted of upland hillsides and swamps, well covered with mixed hardwood stands interspersed with small clearings and roadways with water available. Banks (1884), Currie (1901), and Riley (1902) reported nests being in open woods near water areas."

Keran (1976) found that the average distance of all nests from upland openings (woodland trail, paved road, gravel road or wooded field) was 42 m. None of the nests located in his study were more than approximately 130 m from an upland opening.

Data suggest that the proximity of a wetland habitat may also be important to nesting broad-wings. Keran (1976) found that all nests were

within 154 m of a 'wet area.' Fourteen of 29 nests were an average of 36 m from wooded swamps, including tamarack (Larix lariciana), black spruce (Picea mariana), fir (Abies balsamea), red maple (Acer rubrum) and black ash (Fraxinus nigra). Eight nests averaged 77 m from shrub swamps, including alder (Alnus spp) and dogwood (Corylus spp), whereas the remaining seven were near bullrush (Scirpus spp) and cattail (Typha spp.) swamps, a habitat uncommon in our Study Area.

Certainly a majority of our Study Area can provide nesting habitat for broad-winged hawks. Of particular interest is the Toimi Drumlin Field located in the southern watersheds of the RCNSA. This area provides an array of alder and sedge-dominated stream banks directly adjacent to medium to old-aged aspen and aspen-birch forests.

Food Habits

The literature suggests that amphibians and reptiles are important prey items during the nesting season (Table 2). Much of the data, however, comes from studies conducted in forests south of the boreal region. In the northern forests of the RCNSA, the density of amphibians and reptiles is probably low by comparison. Rusch and Doerr (1972) indicated that this was also the case on their study area in Alberta, Canada. They further state that low densities of amphibians and reptiles is not a limiting factor in the northern distribution of the broad-winged hawk. Their data (Table 3) shows that over one-half of the diet of nestings consisted of young snowshoe hare (Lepus americanus) and ruffed grouse (Bonasa umbellus) (24 and 28 percent biomass, respectively). Next in importance was the meadow vole (Microtus pennsylvanieus, 12 percent biomass) and the red-backed vole (Clethrionomys gapperi, 12 percent biomass). All of these prey species

are present on our area, and all except the meadow vole are considered abundant. It is suggested that these prey species are also commonly taken by broad-winged hawks in northern Minnesota.

Probable Breeding Density.

Of the papers reviewed, only two provided nesting densities that were somewhat applicable to our Study Area. These were provided by Keran (1976) in Wisconsin-Michigan and Rusch and Doerr (1972) in Alberta, Canada (Table 4).

Both estimates by Rusch and Doerr (1972) are considered too low for the RCNSA because broad-wings were only a minor component of the raptor community in Alberta, compared to their much greater importance in the present study. Keran's (1976) estimate is probably the upper limit for our region because of the extensive conifer lowlands that provided marginal or low-density cover on portions of the Study Area. Although a field census is needed and should become an integral part of site-specific monitoring, we feel that the 1400 km^2 area may provide nesting habitat for 175 pairs of broad-winged hawks (Table 4).

RED-TAILED HAWK (Buteo jamaicensis).

Occurrence in the State and General Status.

Red-tailed hawks are one of the three most numerous raptors in the state of Minnesota (Green and Janssen 1975). Their spring migration peaks in early April, whereas their fall migration, spanning from early August through late December, peaking in October (Green and Janssen 1975). Twenty-six years of data from Hawk Ridge, Duluth (data provided by

Janet Green, 1951-76; Copper-Nickel Report #), show that red-tails made up an average of 5.9 percent of all raptors counted in the fall. The literature indicates that red-tail populations have remained relatively stable over time.

Breeding Habitat.

Red-tailed hawks are commonly associated with agricultural or moderately open habitat types. Although these habitats may be more "typical," recent field research in Alberta, Canada (Luttich, et al. 1970; McInvaille and Keith 1974) have emphasized the adaptability of this hawk to forested systems. Luttich, et al. (1970) states that "its skill as a predator, which some earlier workers appear to have downgraded, is evidently sufficient to permit occupation of both open and forest cover types with equal facility."

Red-tails used a variety of nesting sites in Alberta. The habitat within a 1.5 mile (3.9 km) radius of each nest was classified as being primarily open, aquatic or forested (Luttich, et al. 1970). The authors found that:

> "Breeding pairs successfully raised young in open, water and forest cover types in nearly direct proportion to the availability of such habitat....Furthermore, there was a clear tendency for these birds to obtain their food supply from the dominant cover type surrounding the nest, rather than to exploit consistently any particular type."

Both of the above Canadian studies provide sufficient evidence to conclude that red-tailed hawks may represent an important component of the total raptor population on both the 1400 and 5000 km^2 Study Areas. Nevertheless, detailed population studies in northeastern Minnesota are needed to more accurately predict the actual nesting density for the region.

Food Habits

Food habit studies in North America for red-tailed hawks have shown this species to be highly adaptive to local prey conditions. Several earlier studies suggested that mice were the principal food item (Fisher 1893, McAtee 1935), others concluded that ground squirrels formed the major prey (Craighead and Craighead 1956; Fitch, et al. 1946; and Luttich, et al. 1970), while pheasants (Phasianus colchicus) and cottontail rabbits (Sylvilagus floridanus) dominated other food studies (Gates 1972, Orians and Kuhlman 1956). Although the predominant prey specy or species varied, most authors agreed that red-tailed hawks were utilizing the most numerous prey on each study area.

Food habits of red-tails in Alberta, Canada (Luttich, et al. 1970, McInvaille and Keith 1974), are considered the most applicable to our Study Area. The later paper which summarizes Luttich's, et al. work and includes an additional three years of data will serve as the principal reference during the following discussion.

Table 5 includes percent frequency and percent biomass (the latter estimate is considered more important in elevating food habits) of prey brought to nestlings over a seven-year period at Rochester, Alberta. Termination of the study in 1968

would have shown that red-tails preferred Richardson's ground squirrels (Citellus Richardsoni, 31.0 percent biomass) over snowshoe hares (18.5 percent biomass) by nearly 2:1. However, as the snowshoe population increased, hares became the major food item in 1970 and 1971. At the same time, the use of birds dropped substantially from a mean of 34.2 percent biomass (1965-68) to only 14.0 percent biomass (1969-71).

The cyclic increase in snowshoe hares in Alberta (16/100 acres in 1965 to 306/1000 acres in 1971) is strongly reflected in the diet of red-tails (Table 5). Snowshoes increased to such high densities that ruffed grouse, who also experienced a gradual, although slower population increase (15/100 acres in 1966 to 21/100 acres in 1971), were "buffered" and considered a minor prey.

We suggest that red-tailed hawks on our Study Area also depend heavily on the snowshoe hare for food. Other prey may include ruffed grouse, Franklin's ground squirrels (Citellus franklini), least chipmunks (Eutamias minimus), eastern chipmunks (Tamias striatus), red-backed voles, deer mice (Peromyscos maniculatus), waterfowl, and song birds.

Probable Breeding Density.

Although red-tail populations remain relatively stable from year to year, the actual density at any given location is dependent on the amount of favorable habitat present. One measure of habitat quality is to compare the relative abundance of raptors using the same sized area. This comparison for the three studies listed in Table 6 led to the following conclusions relative to the probable nesting densities of red-tails on our Study Area.

1. Red-tails or red-tails and great-horned owls dominated the raptor-breeding population on each of the three study areas. We suspect that our population is dominated by broad-winged hawks and kestrels (Table 1).

2. Open land, predominantly agriculture, occupied from 44 to 90 percent of the total acreage of these three study areas. This same type occupies less than three percent of the land within the 1400 km^2 Study Area.

These two distinct differences, along with field observation data (Table 1), force us to conclude that our 1400 km^2 Study Area is a less favorable habitat for red-tails. As a result, density of this raptor may be substantially lower than found in other areas. Our conservative estimate is that 100 pairs of red-tailed hawks nest on the Study Area (one pair per 14 km^2). A more accurate estimate must await research from a northern forested region where habitat conditions favor the broad-winged hawk.

GOSHAWK (Accipiter gentilis).

Occurrence in the State and General Status.

Goshawks are resident in the northern deciduous and deciduous-coniferous forests of North America. This raptor normally remains in these high latitude regions year-round, with fall migration counts of goshawks at Hawk Ridge, Duluth, accounting for less than two percent of all raptor observations from 1951 to 1976 (data provided by Janet Green, Copper-Nickel Report No.). Periodic and significant increases in the number of observations (e.g., in 1972 and 1973 when 5,382 and 3,517 goshawks were seen) are attributed to cyclic shortages of snowshoe hares and ruffed grouse.

A total of only nine goshawk observations were made in two field seasons on our Study Area (Table 1). The limited number of observations result

partly from the secretive habits of goshawks and accipiters in general. In addition, the species maintains low breeding densities. McGowan (1975) reported an average of only one or two breeding pairs per township in Alaska.

Although goshawks are present in northern Minnesota, the primary breeding range is the forested regions of Canada and Alaska. In these northern boreal forests, goshawks are commonly the only resident hawk species.

Breeding Habitat.

Forest cover requirements of goshawks have only recently been studied. In Alaska, McGowan (1974, 1975) has conducted aerial nest searches in predominantly pure or mixed stands of hardwoods (trembling aspen and paper birch) with scattered spruce. Such forest cover is similar to the predominant upland cover in the RCNSA.

Within the Alaskan forests, McGowan (1974) located 45 nesting sites. Their frequency and distribution within the major forest types were as follows:

FOREST TYPE	NO. OF NEST	PERCENT OF NEST
Birch	17	38
Aspen	8	18
Birch-Aspen	8	18
Birch-Spruce	8	18
Birch-Spruce-Aspen	2	4
Spruce-Cottonwood	2	4
	45	100

Mature hardwood trees, 17-48 cm DBH, were preferred for nesting platforms. Of the 45 nest trees located, 34 were paper birch, nine were aspen and two were cottonwood. Thirty-seven of the 45 nests were located in mature trees growing on hillsides.

Two additional studies, conducted in conifer forests in the western United States, demonstrate that mature conifers are also used as nest sites when widely available. Working in a dense lodgepole pine forest (Pinus contorta) in California, Schnell (1958) located five goshawk nests in lodgepole pine trees. Schuster (1976), working in similar pine forest in Colorado, located ten nests. Although the later author did not report the tree species selected as nest sites, it is assumed that pine were used. Together, all three of the above studies suggest that goshawks are not restrictive in their selection of nesting habitat. Based on this evidence, the diversity in species composition and age of the forests on the RCNSA would appear to provide adequate nesting requirements for this species.

Food Habits.

Goshawks are extremely capable forest predators and utilize a variety of bird and mammal species. They are equally at home when hunting in either closed canopy forest (Zirrer 1947) or in natural or man-made openings (Zirrer 1947, Schnell 1958).

A variety of prey are taken by nesting pairs. Eng and Gullion (1962) demonstrated heavy use of ruffed grouse during spring and summer. Grzybowski and Eaton (1976) found that ruffed grouse were the leading prey brought to ten nest sites in New York state, followed by blue jays,

eastern chipmunks, and red squirrels (Table 7). If the values in this table had been calculated in percent biomass, grouse would have provided approximately 30 to 50 percent of the food brought to young goshawks. Other nesting season studies, however, have indicated only limited use of ruffed grouse. Meng's (1959) data showed heavy utilization of the common crow, followed by red squirrels and various blackbirds (Table 8). Schnell (1958) found that over 60 percent of the prey included song birds (Table 9). A Wisconsin study (Zirrer 1947) suggested heavy use of snowshoe hare during a cycle high.

The winter diet of migrant goshawks in Pennsylvania was dominated by ruffed grouse (Sutton 1931). Of 224 food items identified, 81 (36.2 percent) were ruffed grouse. Cottontail rabbits were the next most common prey (55, 24.6 percent). Other species commonly taken (domestic chicken, bob-white quail, and ring-necked pheasant) are absent or not commonly available to goshawks in northeastern Minnesota.

Within the RCNSA, it is likely that snowshoe hares and ruffed grouse are the primary food items for goshawks during the winter. These prey are probably important throughout the entire year. Clearly, any extensive habitat alteration reducing the density of snowshoe hares and ruffed grouse would seriously reduce the long-term density of goshawks in our region. This has been demonstrated in Alaska where goshawk densities were reduced by 85 percent from one year to the next during a sharply declining hare population and an already low ruffed grouse population (McGowan) 1974). Luttich, et al. (1970) and others have suggested that breeding densities and/or invasion of goshawks from Canada and Alaska to the United States are due primarily to the cyclic nature of these two prey species.

Probable Breeding Density.

Density estimates of nesting goshawks must consider the position of the hare and grouse cycle (previous section). During the present field study (summer 1976, 1977) ruffed grouse were recovering from a low, and snowshoe hares were at or near peak numbers (Copper-Nickel Report No. __ & __). Goshawk breeding densities were studied under similar conditions in Alaska (McGowan 1974). Prey species, densities and habitat similarities make this Alaskan study the most applicable to our region.

Table 10 indicates that as few as four nesting pairs (one pair per 360 km^2) may use the entire 1400 km^2 Study Area during cyclic lows of hares and grouse. We feel that the small study area of Eng and Gullian (1962, 5.2 ml^2) in Minnesota may introduce a considerable bias by extrapolating their density estimates to an area the size of our Study Area. Likewise, the nearly continuous conifer cover (lodgepole pine) on the Colorado study area (Shuster 1976) makes comparisons with our area equally difficult. McGowan's (1974, 1971 to 1973) estimates of one nesting pair per 40 to 50 km^2 are considered the most applicable to our Study Area. We suggest that approximately 30 pairs of goshawks currently may nest on the Study Area (Table 10).

COOPER'S, SHARP-SHINNED AND MARSH HAWKS.

There are three additional species of hawks that commonly nest in the state and occur in northeastern Minnesota. All three belong to the family Acciptridae and are either considered to be scarce everywhere (sharp-shinned hawk), scarce in the northeastern portion of the state

(Cooper's hawk), or uncommon in forested regions compared to other raptor species (marsh hawk, Green and Janssen 1975). The two former species are extremely secretive and thus difficult to work with in the field (Meng 1959). Both Cooper's and sharp-shinned populations have seriously declined in North America, a decline which coincides with the widespread use of the pesticide DDT (Snyder et al., 1973).

Our literature review was unsuccessful in locating any studies relative to these three species that could be directly applied to our Study Area. Craighead and Craighead (1956) did provide density estimates from a mountainous portion of Wyoming that should be considered as only "very rough" figures for Cooper's and sharp-shinned (Table 17). These authors and Bent (1937, 1938) also suggest that the principle prey of these three hawks are song birds (Cooper's and sharp-skinned) and small mammals, primarily Microtus (marsh hawks, Table 19). Habitat requrements are presented in summary Table 18.

We conclude that the lack of detailed ecological studies on forest types similar to those in northeastern Minnesota for Cooper's, sharp-shinned and marsh hawks would seriously reduce any benefit derived from including these species in intensive, long-term monitoring proposals.

AMERICAN KESTREL (Sparrow Hawk, Falco sparverius).

Occurrence in the State and General Status.

Kestrels were the most commonly observed raptor on our Study Area (Table 1), and are one of the most common raptors in Minnesota (Green and Janssen 1975). Balgooyen (1976) concluded that the wide distribution of this hawk probably makes it the most numerous raptor in the United States.

The tendency of kestrels to perch in open areas where they are readily observed may result in repeated observations of the same individual. The relative abundance of this species in the RCNSA, therefore, may be overestimated by data presented in Table 1.

Breeding Habitat.

Kestrels were observed on our area from mid-April to early September (Table 1). Most sitings were on or adjacent to recently-disturbed areas. Of these, recent clearcuts, burns, and gravel pits were most often used. Studies conducted elsewhere (Craighead and Craighead 1956; Smith 1972; Balgooyen 1976; and Heintzelman 1964) suggest a preference for upland openings dominated by grass with deciduous trees being favored for nesting (Smith 1972). The limited availability of such favorable habitat may currently restrict both the density and distribution of kestrels on the RCNSA.

Food Habits.

Kestrels utilize a wide range of prey species. Heintzelman (1964, Table 11) has summarized prey studies from North America. From his own work in Pennsylvania, he found meadow mice (Microtus spp.) and passerines were the most common prey. A study in Utah (Smith 1972, Table 12) also demonstrated heavy use of meadow mice (62.0 percent biomass), followed by deer mice (8.0 percent biomass), and house sparrows (6.0 percent biomass). Since red-backed voles (Clethrionomys gapperi) and deer mice (Peromycus maniculatus) are considerably more abundant than meadow mice in the RCNSA, they are likely to be more important prey items than has been previously reported in other studies.

Probable Breeding Density.

The breeding density and study area descriptions for four different areas are presented in Table 13. Nesting estimates for our 1400 km^2 area, based on these studies, place the potential population at 159 to 500 pairs. All of these study areas were considerably more open than our forested region, and openings are considered a limiting factor affecting both the distribution and density of kestrels on our area. We must conclude that kestrels are nearer the bottom range of densities shown in Table 13 and estimate their abundance at 200 nesting pairs.

GREAT-HORNED OWL (Bubo virginianus).

Of the family Strigidae (the typical owls), only the great-horned owl has been extensively studied. Information on other species is generally fragmented and nonspecific as to habitat use, food habits, and density estimates. For these reasons, only the great-horned owl will be considered in detail.

Occurrence in the State and General Status.

Great-horned owls are resident throughout Minnesota but are somewhat more sedentary in southern regions of the state (Green and Janssen 1975). This species, along with the goshawk, represent the principal component of the resident raptor population in northern forest types. Recent long-term studies in Alberta, Canada (Rusch and Doerr 1972; McInvaille and Keith 1974; Luttich, et al. 1970) have greatly expanded our understanding of how great-horned owls fit into the ecology of northern aspen forest and are the primary references used in the following discussion.

Breeding Habitat.

The Alberta studies indicated that great-horned owls utilized the edge of large forested blocks for nesting when populations were low (Rusch and Doerr 1972, interpreted from nest location maps (p. 285) and habitat presented by McInvaille and Keith 1974). Most nests were associated with upland forest dominated by aspen, with the remainder occurring along upland-lowland (aspen and black spruce-tamarack) edges. As the nesting density increased, more pairs nested in small or isolated woodlots in the generally open farm country.

The diversity of upland and lowland, deciduous and conifer cover in the RCNSA suggests that most areas do contain cover types that will serve as potential habitat for great-horned owls. Mid-aged to mature, upland deciduous and deciduous-coniferous stands within one-half mile of streams are likely to be highly preferred sites. Nesting densities are probably much lower in mature uniform upland and lowland conifer stands with nearly continuous forest canopies.

Food Habits.

An extensive collection of great-horned owl stomachs and pellets was analyzed by Erington, et al. (1940). Of the 4,838 samples analyzed, 68.5 percent contained remains of rabbit or hare. Cottontails were most commonly found and Errington believed that this was the major prey of the great-horned owl in North America. Frequency of use did not fluctuate with known increases or decreases in the rabbit population.

Cottontails were also the major food item during the nesting season in Wisconsin (Orians and Kuhlman 1956). Of 101 food items brought to nest,

43 (42.6 percent) were cottontails and 30 (29.7 percent) were pheasants. Orians and Kuhlman noted that their study area (Green County) was one of the best pheasant areas in the state. Because of the abundance of this prey species "... owls in the study area ate far more pheasants than in any other region where they have been studied." These percentages would have been even greater if the food studies had been expressed on a biomass basis.

An extensive food habit study at Rochester, Alberta, Canada, was conducted by Rusch & Doerr (1972) from 1966 to 1969, with two additional years of data from 1970 and 1971 furnished by McInvaille and Keith (1974, Table 14). The results of these studies appear most applicable to the RCNSA. The primary features of the Alberta food study, based on biomass, are as follows:

1. Snowshoe hare was the predominant food in all years except 1966, when hares and ruffed grouse were equally common (23 percent each). Both prey species are likely to be important in the RCNSA.
2. As the adult snowshoe hare population increased from 16/100 acres in 1965 to 306/100 acres in 1971 (19.1 fold increase, McInvaille and Keith 1974), great-horned owl use of this prey increased more than three times.
3. A 1.4-fold increase in the adult ruffed grouse population from 1966 (15/100 acres) to 1971 (21/100 acres) was met with reduced consumption by owls. This was considered a "buffering" effect caused by the overwhelming increase in snowshoes during the same period.

4. Waterfowl, pocket gophers, mice and voles, ruffed grouse, and sharp-tailed grouse individually provided ten percent or more biomass for one or more years of the study. With the exception of pocket gophers and sharp-tailed grouse, these prey species or groups should also be considered important on our Study Area.

Probable Breeding Density.

The nesting density of great-horned owls in Alberta responded to cyclic fluctuations of snowshoe hares and ruffed grouse (Rusch, et al. 1972; McInvaille and Keith 1974). We must assume that similarities in food habits between the Alberta area and our Study Area exist and will result in similar variations in nesting density.

During a low in the snowshoe hare-ruffed grouse cycle, five and six resident pairs of great-horned owls were present on the Alberta study area (1966 and 1967, respectively, Table 15). Only 20 and 50 percent of these pairs nested, respectively. As the prey population increased, the number of resident pairs more than doubled and breeding (laying) pairs increased 16-fold (Table 15). Their data also show that an area may provide habitat for resident great-horned owls even during lows in the hare-grouse cycle, but reproduction is largely curtailed.

Using the above data, we conclude that our Study Area may provide habitat for as few as 11 or as many as 143 nesting pairs of great-horned owls (Table 16). The minimum number of resident pairs (nesting and non-laying, combined), even during a cyclic low in prey, is probably 56 pairs. Since our study occurred at or near a cyclic peak in the snowshoe hare

population and an increasing ruffed grouse population, we conclude that great-horned owls nesting on our area may total from 81 to 142 pairs (Table 16). A conservative, mid-range estimate would place the nesting population of this raptor at 110 pairs.

OTHER OWLS

The remaining owl species known or suspected of breeding in northeastern Minnesota include the long-eared (Asio otus), short-eared (Asio flammeus), barred (Strix varia), and the saw-whet owls (Aegolius acadicus). Field studies for these species have rarely addressed the specifics of habitat use or avoidance, and demographic information is generally lacking in the literature. The probable breeding density of these owls presented in Table 17 are admittedly "educated guesses." Habitat and prey requirements of these and all other raptors considered in the paper are summarized in Tables 18 and 19.

CONCLUSION

A literature review emphasizing studies from similar forest types provided information for most species of raptors known or suspected of nesting on the RCNSA. Characteristics of habitat use, food preferences, and probable nesting densities are presented separately for those species where such data are available. The relative abundance of the major hawk and falcon species was at least partially substantiated by random field observations by members of the terrestrial biology staff.

We estimate the total breeding population of all raptors at 1,068 nesting pairs (2,136 individuals) on the 1400 km^2 Study Area, with 3,813 pairs (7,626 individuals) residing on the entire RCNSA. It is obvious from the limitations stated in the text and the pertinent tables in this paper that there is no way to place meaningful confidence intervals on these estimates. Such parameters can only be calculated if intensive field studies are conducted in this region at some future date. However, as stated below, we feel that the above density estimates for our Study Area are realistic and may even be quite conservative.

To our knowledge, the total density estimate of all raptors (many of which are also present on our Study Area) on a given unit of land provided by the Craigheads' (Craighead and Craighead 1956) work in Michigan and Wyoming remain the principal guideline today. These authors state (p. 361) that "over large land areas raptors can maintain an average population density as high as one nesting pair per 0.27 square miles (1.48 nesting pair/km^2) in ideal habitat, and even in areas of intensive land use, they can attain an average population density of one nesting pair per 0.56 square miles (0.72 nesting pairs per km^2). They attain a local density as high as one nesting pair per 0.10 square miles (4.0 nesting pairs per km^2)."

Our estimate for all 12 species of raptors known or suspected of breeding on our Study Area from Table 17 places that total breeding density at 1,068 pairs, or 0.76 pairs per km^2. This value is conservative and near the lower limit of 0.72 pairs per km^2 suggested by the Craigheads' work.

There also appears to be ample proof that upland deciduous and coniferous stands, or upland deciduous-coniferous mixtures generally provide more

favorable habitat for raptors considered here than do lowland (primarily spruce or spruce-fir on our Study Area) forest types. Specifics on habitat and prey preference have been given in the appropriate sections of this report and/or are summarized in Tables 18 and 19. When evaluating direct land use for mining operations in the RCNSA and its effect on the total raptor population, we suggest the following density estimates be applied to loss of upland vs. lowland habitat types:

1. For lowlands (spruce-fir-tamarack, unproductive forest, shrub and bog swamps, etc.), calculate the loss of each km^2 of land as equivalent to the potential loss of nesting and/or feeding habitat for 0.50 pair of raptors.
2. For uplands (aspen, aspen-birch, deciduous-coniferous stands, conifer types, shrub communities, etc.), calculate the loss of each km^2 of land as equivalent to the potential loss of habitat for 1.00 pair of raptors.

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TABLE 1. Number and seasonality of raptor observations on the 1400km^2 study area.

Family Accipitridae (Hawks, Eagles & Harriers)		Jan			Feb			March			April			May			June			July			Aug			Sept			Oct			Nov			Dec			observations	
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	total	%
*Goshawk (Accipiter gentilis)	1976																					(2) 1																
	1977	1			1	1						1	1					1																			9	4.7
*Sharp-shinned Hawk (Accipiter striatus)	1976																			1						1												
	1977														1																						3	1.6
*Cooper's Hawk (Accipiter Cooperi)	1976																																					
	1977																																				0	0.0
*Red-tailed Hawk (Buteo jamiacensis)	1976													1	3		2	3			2			1		2		1										
	1977										(2)	1					1,1,2																				22	11.4
Red-shouldered Hawk (Buteo lineatus)	1976																																					
	1977																																					
*Broad-winged Hawk (Buteo platypterus)	1976													1, (2) (3)			3, (2,2) 4,3			(2), 7, (3) 1 4																		
	1977											2			1,2		4,3,1																				51	26.6

PRELIMINARY DRAFT REPORT, SUBJECT TO REVIEW

TABLE 1
continu

		Jan			Feb			March			April			May			June			July			Aug			Sept			Oct			Nov			De			observation	
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	total	%
Swainson's Hawk (Buteo swainsoni)	1976																																					
	1977																																					0	0.0
*Rough-legged Hawk (Buteo lagopus)	1976																																					
	1977										1																											1	0.5
Ferruginous Hawk (Buteo regalis)	1976																																					
	1977																																					0	0.0
Golden Eagle (Aquila chrysaetos)	1976																																					
	1977																																					0	0.0
*Bald Eagle (Haliaeetus leucocephalus)	1976																			1,1						1		1	1			1			1				
	1977										1																											7	3.6
*Marsh Hawk (Circus cyaneus)	1976																			1									1										
	1977																																					2	1.0

TABLE 1 continued

Family Pandionidae (osprey)		Jan			Feb			March			April			May			June			July			Aug			Sept			Oct			Nov			Dec			observation	
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	total	%
*Osprey (Pandion haliaetus)	1976											1						1																				
	1977										1										1																	4	2.1
Family Falconidae Falcons Gyrfalcon (Falco rusticolus)	1976																																					
	1977																																				0	0.0
Prairie Falcon (Falco mexicanus)	1976																																					
	1977																1																					1	0.5
Peregrine Falcon (Falco peregrinus)	1976																																					
	1977																																				0	0.0
*Merlin Pigeon Hawk (Falco columbarius)	1976																																					
	1977																																				0	0.0
American Kestrel or Sparrow Hawk (Falco sparverius)	1976													2,6			1,3,10			3,2,1			2			2												
																	5,5,5																						
	1977										2			2,3			6,8,2			4,4																	78	40.6

TABLE 1. continued

		Jan			Feb			March			April			May			June			July			Aug			Sept			Oct			Nov			Dec			observation	
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	total	%
Family Tytonidae																																							
Barn Owl (Tyto alba)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977																																					0	0.0
Family Strigidae (typical owls)																																							
Screech owl (Otus asio)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977																																					0	0.0
*Great horned owl (Bubo virginianus)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977			1				1				1																										3	1.6
Snowy Owl (Nyctea scandiaca)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977					1																																1	0.5
**Hawk owl (Surnia ulula)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977																																					0	0.0
Burrowing owl (Speotyto cunicularia)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977																																					0	0.0

TABLE 1 continued

		Jan			Feb			March			April			May			June			July			Aug			Sept			Oct			Nov			Dec			Observations	
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	total	%
arred owl tr[illegible] varia)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977					1		1, 1				2						1																				6	3.1
ea[illegible] gray owl tr[illegible] nebulosa)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977																																					0	0.0
ng[illegible]eared owl si[illegible] otus)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977																																					0	0.0
[illegible]ort-eared owl sio flammeus)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977																																					0	0.0
re[illegible] owl egolius Funnereus)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977																																					0	0.0
aw-whet owl egolius Acadicus)	1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	1977										1																											1	0.5

TABLE 1 continued

		Jan			Feb			March			April			May			June			July			Aug			Sept			Oct			Nov			Dec			observations	
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	to	%
Turkey vulture (Cathartes aura)	1976																																					
	1977								1			1						1																				3	1.6
																																					192	99.9

*Nesting records for and currently believed to nest in northeastern Minnesota (Green and Janssen 1975).

**A few breeding pairs may remaine to breed in Minnesota after years of major invasions (Green and Janssen 1975).

2 = circle with number represents suspected pairs or family groups.

• = observed adjacent to Minesite on Regional Copper-Nickel Study Area.

A = only positive identification by qualified member of the Terrestrial or Copper-Nickel Staff are presented in this table.

B = 1=day 1 to 10 of each month
2=day 11 to 20 of each month
3=day 21 to end of month

Table 2. Broad-winged hawk food habits.[A]

1. Burns (1911). Birds, small mammals, reptiles, amphibians, insects

2. Roberts (1931). Snakes, toads, red squirrels, moles, mice, small birds, insects.

3. Errington and Breckenridge (1938). Cottontail rabbits, thirteen-lined ground squirrels, snakes, toads, frogs, insects (15 out of 17 stomachs contained insects with 8 having insects primarily).

4. Rusch and Doerr (1972).
Omitted from this table. see table 3

5. Mosher and Matray (1974).

Mammals and amphibians	74	70.7
Birds	21	6.1
Reptiles	5.7	23.4

6. Keran (1971-1974). Remains found in nests: ruffed grouse chick, pewee, red-backed vole, eastern chipmunk, frogs, various mice, small birds.

A. Table 8 from Keran 1976 P 16.
Modified as noted.

Table 3. Food habits of nestling Broad-winged hawks.A

Prey species[1]	Percent frequency 1966	1968	Total	Percent biomass 1966	1968	Total
Mammals						
Snowshoe hare	3	7	5	23	24	24
Red squirrel	1	0	1	5	0	0
Least chipmunk	2	0	1	4	0	1
Meadow vole	18	20	19	18	10	12
Res-backed vole	36	12	24	28	5	12
Jumping mouse	6	2	4	3	1	2
Deer mouse	1	12	6	1	4	3
Cinerous shrew	5	0	2	tr[2]	0	tr
Total Mammals	72	53	62	82	44	56
Birds						
Ruffed grouse	0	8	4	0	42	28
Blue Jay	1	0	1	1	0	tr
Rose-breasted grosbeak	1	0	1	1	0	tr
Fox Sparrow	1	0	1	1	0	tr
White-throated Sparrow	2	1	2	1	tr	tr
Ovenbird	1	0	1	1	0	tr
Warblers	3	0	2	1	0	tr
Unidentified small birds	15	16	15	13	7	9
Total BIRDS	24	25	27	19	49	38
Amphibians						
Lepard frog	1	0	1	tr	0	tr
Wood frog	1	4	2	tr	tr	tr
Toad	0	13	6	0	7	4
Total AMPHIBIANS	2	17	9	1	7	5
Insects						
Grasshopper	0	4	2	0	tr	tr
Sample[3]	87	83	190	2923	5611	8534

1 Scientific names not mentioned in the text are Tamiasciurus hudsonicus, Eutamius minimus, Zapus hundsonius, Cyanocitta cristata, P heusitcus ludovicianus, Passerella iliaca, Zonotrichia albicollis, Seiurus aurocapillus, Rana spp., and Bufo cognatus.

2 tr=trace; 0.5 percent or less

3 Total numbers of prey individuals and total grams of biomass.

A. Table 2 from Rusch and Doerr 1972, P142.

Table 4. Estimated number of nesting pairs of broad-winged hawks on the 1400 km^2 study area.

SOURCE	YEARS	DENSITY OF NESTING PAIRS	NUMBER OF NESTING PAIRS ON OUR STUDY AREA A
Rusch and Doerr (1972) B	1966-1967	1 pair/13mi^2/ 32.5 km^2	43
	1968-1969	1 pair/6.5mi^2/ 16.2 km^2	86
Keran (1976) C	1971-1974	1 pair/2mi^2/ 5 km^2	280

A. Entire 1400 km^2 area was used in calculating the number of breeding pairs.

B. Rusch and Doerr recorded densities of 1 pair/18m^2 (1966-1967) and 1 pair/9 m^2 (1968-1969) near Rochester, Alberta, Canada. This was on a 36 mi^2 study area where 28% (10mi^2) was cultivated and contained no nesting pairs. This cultivated area has been elliminated when calculating the above density estimates. The remaining 26mi^2 area consisted of one-third deciduous forest (predominantly trembling aspen) and two-thirds bush and bog, with scattered marshes, lakes and ponds.

C. Major study area was located in a forested portion of crow wing county in north-central Minnesota. The forest was primarily mid-old aged oak-aspen-birch with 28% of the area in wetlands.

Table 5--Food habits of nesting Red-tailed Hawks near Rochester, Alberta. Numbers of nests during 1965-1971 were 10,16, 15, 13, 17, and 13, respectively[1]A

	Percent frequency							Percent biomass						
Prey species[2]	1965	1966	1967	1968	1969	1970	1971	1965	1966	1967	1968	1969	1970	1971
Richardson's ground squirrel	17	21	13	25	22	32	26	23	42	25	34	39	38	38
Snowshoe hare	5	2	4	7	6	14	21	25	8	17	24	21	46	52
Franklin's ground squirrel	1	4	5	6	4	tr[3]	3	1	5	7	7	5	1	3
Mice and voles	28	32	41	13	34	40	30	3	5	6	2	5	4	2
Other mammals	6	5	6	4	4	1	4	7	6	9	4	3	1	2
Total mammals	64	66	73	67	79	87	86	59	66	64	75	79	90	90
Waterfowl	5	8	12	11	5	4	5	9	18	29	11	11	6	7
Ruffed Grouse	3	2	1	6	3	2	1	7	2	1	5	4	3	1
Sharp-tailed Grouse	0	1	1	1	1	1	1	0	2	2	2	1	1	1
Unidentified grouse	1	1	1	0	1	0	1	3	4	2	0	2	0	0
Other birds	27	23	12	15	8	6	7	23	10	5	7	3	2	2
Total birds	36	34	26	32	21	13	14	41	34	37	25	21	11	10
Total	100	100	99	99	100	100	100	100	100	100	101	100	101	100

[1]Total numbers of food items were 210, 695, 1063, 585, 563, 879, and 545 in 1965 through 1971. Biomass totals (in grams) were 55,479; 167,208; 255,016; 199,851; 161,586; 298,860; and 215,637 in 1965 through 1971.

[2]Prey not specifically identified in the table were the following: "Mice and voles" —*Microtus pennsylvanicus* (averaged 88% of small-mammal biomass), *Peromyscus maniculatus* (2%), *Clethrionomys gapperi* (10%), *Zapus hudsonius* (trace), and *Sorex c. cinereus* (trace). "Other mammals" —*Ondatra zibethicus*, *Tamiasciurus hudsonicus*, *Thomomys talpoides*, *Glaucomys sabrinus*, *Mustela frenata*, *M. rixosa*, *M. erminea*. "Waterfowl" —*Anas platyrhynchos*, *A. acuta*, *A. strepera*, *A. discors*, *A. carolinensis*, *Mareca americana*, *Spatula clypeata*, *Aythya americana*, *A. collaris*, *A. affinis*, *Fulica americana*, *Bucephala albeola*, *Podiceps grisegena*. "Other birds" — *Falco sparverius*, *Accipiter cooperii*, *Columba livia*, *Perdix perdix*, *Pica pica*, *Perisoreus canadensis*, *Charadrius vociferus*, *Colaptes auratus*, *Dendrocopos villosus*, *Sphyrapicus varius*, *Sturnus vulgaris*, *Turdus migratorius*, *Dendroica petechia*, and unidentified songbirds and domestic chickens.

[3]Less than 0.5%.

A Table 9 from McInvaille and Keith, 1974.

Table 6. Estimated number of nesting pairs of red-tailed hawks on the 1400 km^2 study area.

Source		Year(s)	Density of Breeding pairs	Number of breedingppairs in our study area A
McInvaille and Keith 1974	B	1966-1971	1 (laying) pair / 3.2 mi^2/8.0 km^2	175
Hagar 1957	C	1952	1 nesting pair/3.2 mi^2/8.8 km^2	159
Orians and Kuhlman 1956	D	1954 1955	1 nesting pair /2.9 mi^2/7.2 km^2	194

A. Entire 1400 km^2 area was used in calculating the number of breeding pairs.

B. Rochester, Alberta, Canada 62.5 mi^2 study area. Entire area used in breeding pair estimates because red-tails nested in proportion to available open (farm), aquatic and forested cover. Their study area was 44% agriculture (dominated by aspen, Populus tremuloides and P. balsamifera), 11% brush (all shrub-dominated habitat and/or completely burned over areas), 9% bog-meadow (wet sedge areas, usually associated with forest stands) 2% aquatic (sedge, bullrush and cattail marshes and open water).

C. 50% farm and 50% forested, 52 mi^2 study area on northern edge of Appalachian Plateau in New York State. Entire area used to estimate nesting pairs. Area has long parallel rides, and valley walls are 300-500 ft. high. Crops in valley, slopes forested, uplands pastured and many woodlots. Dominant species are sugar maple (Acer saccharum), beech (Fagus grandifolia)and white ash (Fraxinus americana). Lowland swamps with arborviate (Thuya occidentalis), white pine (Pinus strobus) and hemlock (T. canadensis).

D. Approximately 10 percent of the 95 mi^2 study area in southern Wisconsin was forested, remainder being farmland (crops and pasture).

Table 7. Food Habits of nesting goshawks.[A]

	M[1]	A	M	J	J	A	Total	Percent Total
Birds								
Ruffed Grouse (Bonasa umbellus)	1	4	3	3	2	1	14	18.2
American Woodcock (Philahela minor)	-	1	-	2	-	-	3	3.9
Common Flicker (Colaptes auratus)	-	-	1	-	3	-	4	5.2
Blue Jay (Cyanocitta cristata)	-	-	1	4	2	2	9	11.7
Common Crow(Corvus brachyrhynchos)	-	1	-	3	-	-	4	5.2
American Robin (Turdus migratorius)	-	1	-	1	-	-	2	2.6
Thrush sp. (Catharus sp.)	-	-	-	-	1	1	2	2.6
Eastern Meadowlark (Sturnella magna)	-	1	-	2	-	-	3	3.9
Other birds[2]	-	-	3	2	1	-	6	7.8
MAMMALS								
Eastern Chipmunk (Tamias striatus)	1	3	4	3	1	-	12	15.6
Gray Squirrel (Sciurus carolinensis	-	-	1	4	-	-	5	6.5
Red Squirrel (Tamiasciurus hudsonicus)	-	1	4	4	-	-	9	11.7
Other mammals[3]	-	1	3	-	-	-	4	5.2
							77	100.1

1 Months in chronological order beginning with March.
2 Other birds included 1 each of the following: Common snipe (Capella gallinago), starling (Sturnus vulgaris), Scarlet Tanager (Piranga olivacea), blackbird sp. (Ieteriadae, warbler sp. (Paruliadae,unidentified bird.
3 Other mammals included: 1 deermouse (Peromyscus sp.), 1 eastern cottontail (Sylvilagus floridanus), and 2 unidentified.

A. Table from J.A. Grzybowski and S.W. Eaton, 1976. Their table No. 1. Study conducted in New York State, 1964-1973.

Table 8. Analysis of Pellet and Prey remains at goshawks nests.[A]

Species		Number of times found
Birds		
Sparrow Hawk (*Falco sparverius*)		3
Ruffed Grouse (*Bonasa umbellus*)		5
Blue Jay (*Cyanocitta cristata*)		7
Common Crow (*Corvus brachyrhnchos*)		83
Blackbird (*Euphagus*, *Quiscalus*, *Agelaius*)		15
TOTALS	7	113
Mammals		
Cottontail (*Sylvilagus sp.*)		7
Eastern Chipmunk (*Tamias striatus*)		3
Gray Squirrel (*Sciurus carolinensis*)		4
Red Squirrel (*Tamiasciurus hudsonicus*)		58
TOTALS	4	72
TOTALS	11	185

A. Table from H. Meng, 1959. His table No. 2 (Study from New York and Pennsylvania).

Table 9. Food habits of nestling goshawks.[A]

	Total numbers	Percent	Total weight(in gms.)	Percent
Robin	27	30.7	1285	21.4
Steller's Jay	22	25.2	1356	23.1
Citellus lateralis	6	6.8	700	12.0
Chickaree	5	5.7	594	10.2
Eutamias sp.	5	5.7	226	3.9
Tanager (nestling)	4	4.6	89	1.6
Citellus beldingi	3	3.4	575	9.8
Mallard ducklings	3	3.4	185	3.1
Audubon Warbler	1	1.1	12	.2
Snowshoe Hare	1(leg)	1.1	100	1.8
Scapanus latimanus	1	1.1	67	1.4
Weasel	1	1.1	45	.8
Williamson Sapsucker	1	1.1	42	.7
Pigeon	1	1.1	140	2.4
Mountain Quail	1	1.1	26	.4
Unknown				
Mammals	5	5.7	399?	6.8
Birds	1	1.1	25	.4
Totals	88	100.0	5866	100.0

A. Table from J.H. Schnell, 1958. His table No. 1 (Study from California).

Table 10. Estimated number of nesting pairs of goshawks on the 1400 km^2 study area.

Source	Year(s)	Density of Breeding pairs	Number of breeding pairs on our study area A
Eng and Gullion 1962 B	1957-1961	1 nesting pair /5.3 mi^2/13.3 km^2	105
Mc Gowan 1974 C	1971-	1 nesting pair /16 mi^2/40 km^2	35
	1973	1 nesting pair /21 mi^2/52.5 km^2	27
	1974	1 nesting pair /144 mi^2/360 km^2	4
Schuster 1976 D	1974-1975	1 nesting pair /5.3 mi^2/13.3 km^2	105

A. Entire 1400 km^2 area was used in calculating the number of breeding pairs.

B. The authors felt conifedent that all nesting goshawks on the 5.3 mi^2(63.8km^2) ruffed grouse study area near Cloquet, Minnesota had been located. Only in 1956 were 2 pairs known to nest on the area, and this data is not included in this table. The remainder of the time one pair was present. The habitat on the area was dominated by aspen-jack pine uplands, with conifer and shrub lowlands.

C. Densities of goshawks between 1971-73 represent the range during high prey (primarily snowshoe hare) years. The 1974 estimate was during a snowshoe hare low. Author felt he found at least 75% of nest on the 144 mi^2(372 km^2) interior Alaska Study Area. Forest cover primarily mature trembling aspen, paper birch, aspen-birch, or aspen-birch-spruce. North slopes scrubby black spruce too small to be used for nest trees.

D. Six nestling pair each year on 32.5 mi^2 (81 km^2) study area in northern Colorado. Forest cover included extensive stands of lodge pole pine (Pinus contorta) with interspersed trembling aspen in a Rocky Mountain Valley and ridge terrain. Valley cover included sage (Artemisia) with willow (Salix). Parts of the valley were restricted.

Table 11. General food survey of sparrow hawks.[A]

Prey	Authority
Insects	
Orthoptera	Breckenridge and Errington (1938)
Lesser Migratory Grasshopper (*Melanoplus atlanis*)	McAtee (1932:378)
Grasshopper (*Melanoplus devastator*)	Bryant (1918:127)
Crickets (*Gryllus*)	Breckenridge and Errington (1938)
Jerusalem Crickets (*Stenopelmatus irregularis*)	Bryant (1918:127)
Hemiptera	Knowlton and Telford (1947)
Periodical Cicada (*Magicicada septendecim*)	This study
Aeshnic Dragonflies (Libellulidae)	Locke (1961:342)
Libellulid Dragonflies (Libellulidae)	Locke (1961:342)
Lepidoptera	Breckenridge and Errington (1938)
Acraea Moth (*Estigmene acraea*)	Locke (1961:342)
Coleoptera	Breckenridge and Errington (1938)
Ground Beetle (Carabidae)	This study
Click Beetle (Elateridae)	Knowlton and Telford (1947:311)
Ants (Hymenoptera)	Brodkorb (1928:213)
Diptera maggots	Knowlton and Telford (1947:311)
Reptiles	
Lizard (*Anolis*)	Danforth (1934:357)
Six-lined Racerunner (*Cnemidophorus sexlineatus*)	Lamore (1963:461)
Five-lined Skink (*Eumeces fasciatus*)	This study
Birds	
Ground Dove (*Columbigallina passerina*)	McAtee (1935:35)
Passeriformes	This study
Horned Lark (*Eremophila alpestris*)	Lamore (1963:461)
Cliff Swallow (*Petrochelidon pyrrhonota*)	Bonnot (1921:136)
Winter Wren (*Troglodytes troglodytes*)	McAtee (1935:35)
Carolina Wren (*Thyrothorus ludovicianus*)	Fisher (1893:125)
Robin (*Turdus migratorius*)	Lamore (1963:461)
Eastern Bluebird (*Sialia sialis*)	Drinkwater (1953:215)
Vireo (Vireonidae)	Fisher (1893:121)
Warbler (Parulidae)	McAtee (1935:35)
Hermit Warbler (*Dendroica occidentalis*)	Grinnell (1933:236)
English Sparrow (*Passer domesticus*)	Sage (1893:207)
Icteridae	This study
Cowbird (*Molothrus ater*)	This study
Meadowlark (*Sturnella*)	McAtee (1935:35)
Eastern Meadowlark (*Sturnella magna*)	This study
Red-wing (*Agelaius phoeniceus*)	Fisher (1893:125)
Common Grackle (*Quiscalus quiscula*)	This study
Cardinal (*Richmondena cardinalis*)	This study
Grasshopper Sparrow (*Ammodramus savannarum*)	This study
Vesper Sparrow (*Pooecetes gramineus*)	Fisher (1893:122)

Table 11 cont'd

Prey	Authority
Birds (*Continued*)	
Junco (*Junco*)	Fisher (1893:122)
Sparrow (*Spizella*)	McAtee (1935:35)
Tree Sparrow (*Spizella arborea*)	Wharton (1930:141)
Chipping Sparrow (*Spizella passerina*)	McAtee (1935:35)
Field Sparrow (*Spizella pusilla*)	Fisher (1893:124)
Gambels Sparrow (*Zonotrichia leucophrys gambelii*)	Michener (1930:212)
Sparrow (*Melospiza*)	McAtee (1935:35)
Song Sparrow (*Melospiza melodia*)	Broun (1932:119)
Mammals	
Shrew (Soricidae)	Fisher (1893:122)
Short-tailed Shrew (*Blarina brevicauda*)	Fisher (1893:126)
Big Brown Bat (*Eptesicus fuscus*)	Stoner (1939:474)
Mexican Free-tailed Bat (*Tadarida brasiliensis mexicana*)	Baker (1962:500)
Striped Ground Squirrel (*Citellus tridecimlineatus*)	Breckenridge and Errington (1938: 669–670)
Gopher (Geomyidae)	Fisher (1893:123)
Mice (*Peromyscus*)	Breckenridge and Errington (1938)
Deer Mouse (*Peromyscus maniculatus*)	Tordoff (1955:140)
White-footed Mouse (*Peromyscus leucopus*)	Fisher (1893:126)
Cotton Rat (Cricetinae)	Fisher (1893:126)
Wood Rat (Cricetinae)	Widmann (1896:222)
Microtinae	This study
Mice (*Microtus*)	Breckenridge and Errington (1938)
Meadow Mouse (*Microtus p. pennsylvanicus*)	Poole (1932:56)
Prairie Vole (*Microtus ochrogaster*)	Tordoff (1955:140)
House Mouse (*Mus musculus*)	Fisher (1893:122)
Meadow Jumping Mouse (*Zapus hudsonius*)	This study
Rabbit (Leporidae)	Fisher (1893:123)
Miscellaneous	
Bread	Warburton (1952:85)

A. Table from Heintzelman 1964, P,326-328. His table 2. See Heintzelman paper for bibliography of papers cited in table.

Table 12. Food habits of the American Kestrel in central Utah, 1967-1970

Locustidae	329	39.0	122.0	1.0
Aeschnidae	37	4.0	37.0	0.6
Libellueidae	173	21.0	57.0	0.8
Coenagronidae	16	2.0	0.3	TR*
Gryllidae	81	10.0	19.0	0.3
Hemiptera	2	0.2	0.2	TR
Tenebrionidae	3	0.4	1.5	TR
Lepidoptera	27	3.0	18.0	0.3
Rana pipiens	9	1.0	245.0	4.0
Rana pretiosa	1	0.1	25.0	0.4
Cnemidophorous sp.	2	0.2	160.0	3.0
Falco sparverius	1	0.1	75.0	1.0
Passer domesticus	13	2.0	390.0	6.0
Sturnis vulgaris	3	0.4	188.0	3.0
Agelaius phoeniceus	2	0.2	300.0	5.0
Sorex vagrans	3	0.4	36.0	0.6
Peromyscus sp.	25	3.0	525.0	8.0
Microtus sp.	98	13.0	3920.0	62.0
Mus musculus	11	1.0	198.0	3.0
Totals (19 prey)	836	99.8	6317.0	99+

*Trace amounts.

A. Table from Smith et.al. 1972. His table no. 3, P 81. Study conducted from 1967-1970.

Table 13. Estimated number of nesting pairs of American kestrels on the 1400 km^2 study area.

Source	Year(s)	Density of Nesting Pairs	Number of breeding pairs on our study area A
Smith et al. 1972 B.	1969 1970	1 pair/1.5 mi^2/3.8 km^2	368
Enderson 1960 C.	1960?	1 pair/3.4 mi^2/8.5 km^2	165
Craighead-Craighead 1956	1942 D.	1 pair/2.3 mi^2/5.8 km^2	241
	1947 E.	1 pair/1.1 mi^2/2.8 km^2	500

A. Entire 1400 km^2 area used in calculating the number of breeding pairs.

B. Estimate from outside of abandoned steel mill complex used. Study area was in a valley in Utah where land use was primarily farming and orchards. Only scattered trees or clumps of trees were present.

C. 43 mi^2 (111.8 km^2) study area in fertile farm land in Illinois. Less than 5% of land is forest.

D. Michigan study area 37 mi^2 (96.2 km^2). 83% farm land or abandoned fields, 12% woodlots, remainder in swamps and marshes.

E. Wyoming study area 12 mi^2 (31.2 km^2). Approximately 60% forested, 20% sage brush.

Table 14. Food habits of nesting Great horned owls.[A]

Prey species[2]	Percent frequency						Percent biomass					
	1966	1967	1968	1969	1970	1971	1966	1967	1968	1969	1970	1971
Snowshoe hare	2	4	10	8	13	27	23	34	50	50	77	81
Pocket gopher	11	7	19	21	2	9	15	6	10	14	1	3
Mice and voles	68	69	54	55	80	48	18	11	6	8	12	4
Other mammals	4	3	3	1	1	2	12	7	6	1	1	1
Total mammals	85	83	86	85	96	86	68	58	72	73	90	89
Ruffed Grouse	4	2	2	0	tr[3]	tr	23	6	4	0	1	tr
Sharp-tailed Grouse	0	tr	3	1	tr	tr	0	2	10	3	tr	tr
Waterfowl	1	4	4	6	2	7	7	20	10	18	7	9
Other birds	4	10	5	8	3	5	2	14	3	6	1	2
Total birds	9	16	14	15	5	13	32	42	27	27	10	11
Totals	100	99	100	100	101	99	101	100	99	100	100	100

[1]Total numbers of food items were 114, 986, 518, 338, 756, and 775 in 1966 through 1971; biomass totals (in grams) were 12,103; 174,786; 140,027; 71,778; 193,736; and 321,489, respectively.

[2]Prey not specifically identified in the table were the following: "Mice and voles" — *Microtus pennsylvanicus* (averaged 78% of small-mammal biomass), *Peromyscus maniculatus* (20%), *Clethrionomys gapperi* (2%), *Zapus hudsonius* (trace), and *Sorex c. cinereus* (trace). "Other mammals" — *Ondatra zibethicus*, *Tamiasciurus hudsonicus*, *Spermophilus richardsonii*, *S. franklinii*, *Glaucomys sabrinus*, *Mustela frenata*, *M. rixosa*, *M. erminea*. "Waterfowl" — *Anas platyrhynchos*, *A. acuta*, *A. strepera*, *A. discors*, *A. carolinensis*, *Mareca americana*, *Spatula clypeata*, *Aythya americana*, *A. collaris*, *A. affinis*, *Fulica americana*, *Bucephala albeola*, *Podiceps grisegena*, *Porzana carolina*, *Rallus limicola*. "Other birds" — *Falco sparverius*, *Accipiter cooperii*, *Buteo jamaicensis*, *Columba livia*, *Perdix perdix*, *Pica pica*, *Perisoreus canadensis*, *Charadrius vociferus*, *Colaptes auratus*, *Dendrocopos villosus*, *Sphyrapicus varius*, *Sturnus vulgaris*, *Turdus migratorius*, *Dendroica petechia*, and unidentified songbirds and domestic chickens.

[3]Less than 0.5%.

A. Table from McInvaille and Keith 1974. Their table 8. (Study conducted in Alberta, Canada).

Table 15. Some population statistics for the great horned owl in Alberta, Canada. A.

	1966	1967	1968	1969	1970	1971
Resident pairs	5	6	8	9	?[1]	?
Breeding (laying)	1	3	8	9	7	16
Non-breeding (non-laying)	4	3	0	0	?	?
Eggs hatched/breeding pair[2]	2.0	2.3	2.1	1.9	3.1	2.0
Percent mortality of young from hatching to fledging[3]	0	11	25	19	14	9

[1]Increased number of owls and apparent movements from winter hooting positions to spring nesting sites prevented accurate estimates of total resident pairs.

[2]These figures include some nests not on the 62.5-square-mile area: i.e., one in 1966, five in 1967, three in 1968, one in 1969, two in 1970, and six in 1971.

[3]Young dying from handling and starvation were treated as unnatural mortality and excluded from this sample because such losses did not appear among untethered birds off the study area.

A. Table from McInvaille and Keith, 1974. Their Table 3. 1966 data from 50 mi^2 study area. Remaining years from 62.5 mi^2 area.

Table 16. Estimated number of resident and nesting pairs of great horned owls on the 1400 km^2 study area.[A]

Source	Year(s)	Pair Density[A]	Number of pairs on our study area[B]
Orians and Kuhlman (1956) C.	1953	1np/4.5 mi^2/11.2 km^2	125
	1954	1np/5.0 mi^2/12.5 km^2	112
	1955	1np/8.3 mi^2/20.7 km^2	68
McInvaille and Keith (1974) D.	1966	1np/50mi^2/12.5 km^2	11
	1969	1np/6.9 mi^2/17.2 km^2	81
	1971	1np/3.9 mi^2/9.8 km^2	143
	1966	1rp/10.0 mi^2/125 km^2	56
	1969	1rp/6.9 mi^2/17.2 km^2	81

A. Resident pairs (rp) include nesting and non-nesting pairs. Nesting pairs (np) includes nesting (laying) pairs only.

B. Entire 1400 km^2 area used in calculating the number of pairs present.

C. See table 6 for description of study area.

D. See table 6 for description of study area.

Table 17. Current estimates of the number of breeding pairs of hawks and owls on the 1400 km^2 and 5000 km^2 Copper-Nickel Study Area.[A]

	1400km^2	5000km^2
Broad-winged hawk[B]	175	625
Red-tailed Hawk[B]	100	357
Goshawk[B]	30	107
Copper's hawk[B_1]	50	178
Sharp-shinned hawk[B_1]	93	332
Kestrel-Hawk[B]	200	714
Marsh hawk[B]	10	36
Great horned owl[B]	110	393
Long-eared owl[C]	75	268
Short-eared owl[C]	50	178
Barred owl[C]	100	357
Saw wet owl[C]	75	268
TOTALS	1068	3813
No. of raptor pairs/km^2	0.76	0.76

A. See text for studies used to calculate density estimates. Entire unit area of both Study Areas used for determining densities.

B. Values calculated from the Literature. See text.

B_1. Calculated from Craighead and Craighead 1956 from their Wyoming Study Area. See Table 13 for description of their Study Area.

C. Values considered to be conservative estimates by the authors of this paper. Literature information is not available.

Table 18. Habitat Requirements of Raptors.

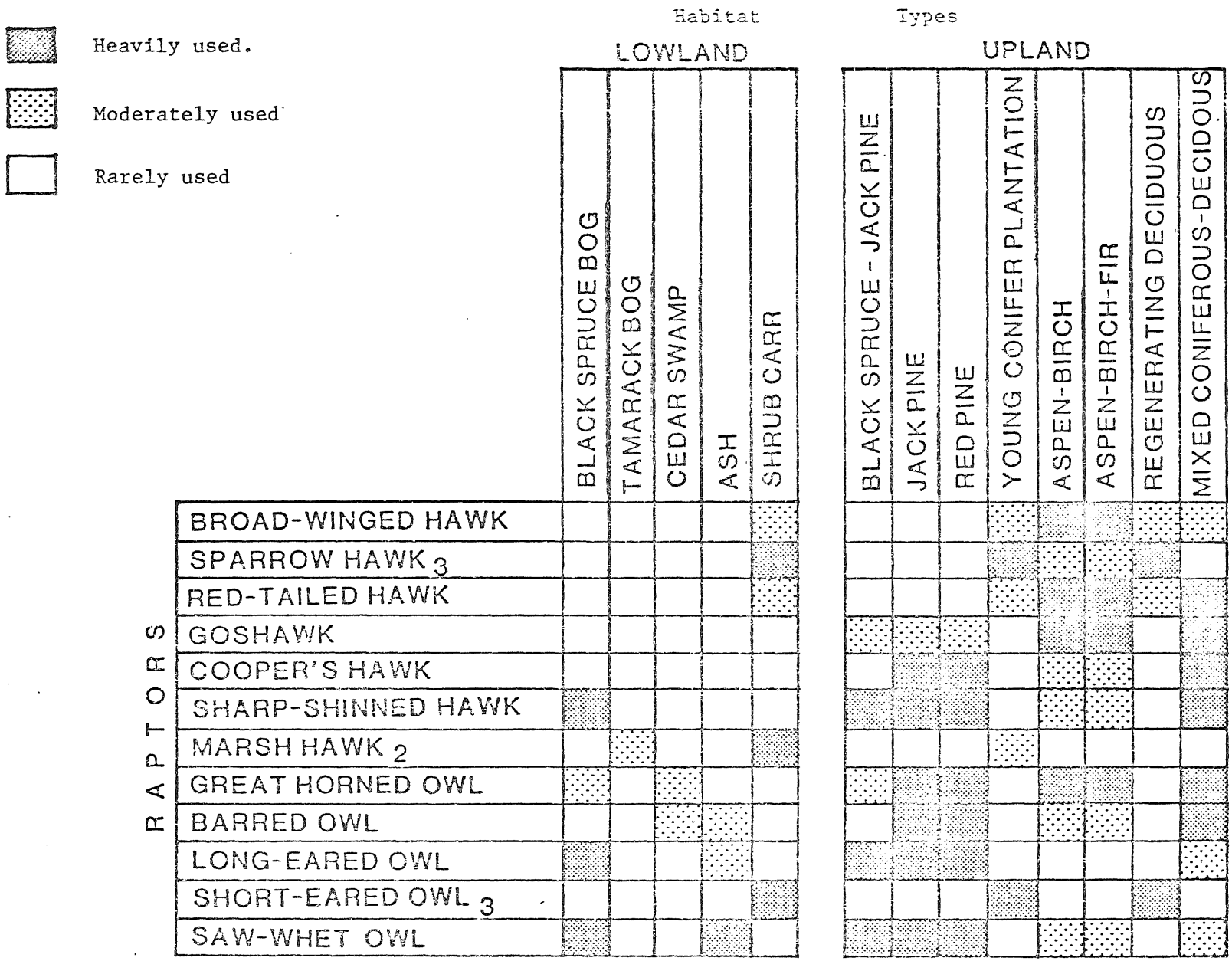

Table 19. Prey selected by raptors.