THE DIETS AND BREEDING BIOLOGY OF RED-TAILED HAWKS IN BOULDER COUNTY: 1985 NESTING SEASON

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ABSTRACT

I studied red-tailed hawks in Boulder County, Colorado during their 1985 nesting season. The purposes of this project were to study red-tailed hawk breeding biology and nesting-season diets and then to make management recommendations based on these results and an understanding of past raptor management.

Numbers of red-tailed hawks winter and nest in Boulder County, Colorado. Boulder County also has five major ecosystem-types (Marr, 1964). The study was designed to be less interventive than many previous studies of raptor food habits had been. Pellet contents and other remains, collected beneath nests, were identified. Red-tailed hawks have been said to consume at least 247 species of animals. At least 31 mammalian and six avian species were identified by pellet analysis to be consumed by red-tailed hawks in Boulder County.

Nine nests in three of the five habitat-types (Plains Grassland, Lower Montane, Upper Montane) were studied. One to 1.7 juvenile hawks fledged per nest.

The evolution of human attitudes and management practices about raptors (specifically red-tailed hawks where possible) were surveyed. Red-tailed hawks and other raptors have been persecuted for years. The 1972 Migratory Bird Treaty Act provided protection for raptors by requiring permits before handling them. Red-tailed hawks are commonly used by falconers. In Colorado, young red-tailed hawks can be removed from a nest to be used for falconry. The falconer must have a proper permit and must leave two young in the nest.

I outline possible future studies which could be conducted by volunteers. The use of strychnine and other secondary poisons, used for prairie dog control and could then indirectly kill raptors, should be discontinued. Finally, I suggest that the Colorado Division of Wildlife monitor red-tailed hawk nests to assure two young are left in the nest by falconers.

INTRODUCTION

Food habits and the breeding ecology of free-living red-tailed hawks (*Buteo jamaicensis*) have been studied extensively. Despite the plethora of studies, no major study has been conducted in Colorado. Olendorff (1973) studied diets of other nesting raptors, but largely ignored the red-tailed hawk because it was not abundant on the Pawnee National Grassland.

The purposes of this study were to provide some information on the 1985 nesting-season diets of red-tailed hawks in Boulder County in different ecosystems. These results, and an understanding of past raptor management, would be used in formulating management recommendations.

This section of the paper provides information about the status, life history, and diet of red-tailed hawks that is helpful in understanding the methods chosen. A brief survey of various methods of raptor food study is presented. Habitat selection and some methods of habitat analysis are discussed as are human attitudes about raptors.

Status

Red-tailed hawks are common diurnal raptors in North America (Brown and Amadon, 1968). Red-tailed hawks probably are the second most common raptor in Colorado (Gerald Craig, pers. comm.). Red-tailed hawks winter and nest in Boulder County, Colorado. In 1972, Henny reported that populations of red-tailed hawks were stable throughout their range. Red-tailed hawks have suffered the effects of egg-shell thinning that have afflicted many species of raptors, but to a lesser degree than many other kinds (Anderson and Hickey, 1972; Braun et al., 1977; Henny, 1972; Henny and Wight, 1972; Hickey and Anderson, 1968; Seidensticker and Reynolds, 1971). This may be due to a smaller proportion of fish in the diet (Peterson, 1969).

Life History

Red-tailed hawks exhibit sexual dimorphism in size. Adults are between 560 and 635 mm long (Beebe, 1974). Males weigh around 1000 g, whereas females weigh around 1200 g (Beebe, 1974; Brown and Amadon, 1968). Differences in size influence food requirements and may be important in niche partitioning and expanding the prey base of the pair (Andersson and Norberg, 1981; Craighead and Craighead, 1956).

Red-tailed hawks vigorously maintain hunting and nesting territories. A pair (generally mated for life) controls the territory which commonly has a radius of approximately 1.7 km (APPENDIX I). Perches, which provide a good overview of the surrounding area, are an important feature of a territory (Fitch et al., 1946). Territorial defense varies in form and intensity, declining as the season progresses (Craighead and Craighead, 1956). Territories may be re-occupied in subsequent years if the hawks are migratory (Hagar, 1957). Gates (1972) observed red-tailed hawks wintering in areas that later became nesting territories. These observations helped locate nests and determine potential hunting areas.

Old nests usually are modified and reused in successive years (Bailey, 1918; Fitch et al., 1946; Luttich et al., 1971; Orians and Kuhlman, 1956). The pair may maintain or build several nests early in the nesting season to be used in case of harassment or early nesting failure (Fitch et al., 1946). It is easiest to locate old nests in deciduous trees during the winter when the leaves are absent (Craighead and Craighead, 1956; Hagar, 1957; Orians et al., 1956). Behaviors, such as defensive displays and vocalizations, are another good indicator of a local nest (Craighead and Craighead, 1956). These observations initially focused the search for nests in the present study.

Nest construction sometimes begins as early as late January, but may begin later. Nevertheless, incubation does not begin that early (Fitch et al., 1946; Hagar, 1957; Orians et al., 1956). In the western United States, nest construction has been observed between 6 February and 25 March (Call, 1978). Green twigs are found in occupied nests (Beebe, 1974; Bennett and Rudersdorf, 1980; Call, 1978; Hamerstrom and Hamerstrom, 1951; Wimberger, 1984). "Whitewash" is visible beneath nests (Johnson, 1975).

Beebe (1974:82) noted that egg-laying began ". . .as early as February in Mexico and across the southern United States, by March or early April in the region of Puget Sound, by mid-April across mid-Canada, and as late as early June in the extreme north." In the western United States, eggs have been observed to be laid from 8 March to 17 April. The red-tailed hawks' breeding season (from laying to fledging) is approximately 112 days long (APPENDIX I).

Generally, 90% of red-tailed hawk pairs lay on average 2.5 eggs. The remaining 10% do not lay eggs in a given year. Both sexes incubate the eggs (Bent, 1937) for approximately 32 days. Brood sizes average 2.1 young. Of those young that hatch, 64% survive to fledge (APPENDIX I). The parents actively defend their young. The surviving young have been observed to fledge between 16 May and 1 July (Call, 1978). Once fledged, the young may stay in the vicinity of the nest for several days (Fitch et al., 1946).

Diet

The diets of free-living red-tailed hawks have been studied extensively elsewhere, but never in Colorado (see Appendix III for farily complete list). The young are brought the same kinds of food that adults eat (small mammals, reptiles, amphibians, insects, fish, crustaceans, and birds). Initially, the adults tear up the prey into smaller pieces; later, entire carcasses are deposited in the nest for the chicks to feed on by themselves. At first, the chicks only eat the flesh and viscera. Because parents try to remove all uneaten prey from the nest within a day, it would be difficult to rely only on nest remains for an accurate food study.

Beebe (1974:78) identified a problem with food studies of red-tailed hawks when he noted that,

> studies of the food habits and hunting methods of this hawk made in a specific region, or even at a specific time of year, do not necessarily indicate the kind of prey taken, or the hunting methods used by the same

> species elsewhere, or even of the same birds in the same area at a different time of the year. Their behavior and food habits are in fact so variable that two individuals living close together in the region and at the same time of year may have food preferences and hunting habits quite as different as if they were two separate species.

Adamcik et al. (1979) noted that diet varies in response to fluctuations in populations of prey species. During a snowshoe hare (*Lepus americanus*) population decline, they observed the mean daily biomass of snowshoe hares in the diet of red-tailed hawks decreasing while the mean daily biomass of other prey species (ground squirrels, voles, mice, various birds) increased.

Food Studies

Various quantitative methods of determining diets of raptors have been developed (Craighead and Craighead, 1956; Errington, 1932). They include field observations, nest studies, stomach examinations, gullet examinations, pellet analysis, tethering (reviewed by Errington, 1932), and the "cage nest" method, discussed by Selleck and Glading (1943). This section will discuss these methods and provide some background for the method chosen.

Some of these methods are more harmful to the bird than others. Stomach examinations not only kill the bird, but they provide only limited data (based upon stomach contents when shot). However, at one time this was the accepted method and was used as recently as 1949 by Latham (1950). It was not uncommon to find 22% of those stomachs examined to be empty (APPENDIX I). Yet, as Olendorff (1973) has discussed for other aspects of raptor studies, "our current, extensive knowledge. . .is [in part], regardless of such detrimental effects, the result of this research" (Olendorff, 1973:24). Therefore, while we do not have to continue using these methods, we should not discard the data they generated.

Gullet examinations, tethering, direct nest studies (i.e., regular nest-tree climbing), and the "cage nest" method also are interventive. Although they do not usually kill the birds being studied, they undoubtedly produce unnecessary stress for the adults and young involved.

> If man is going to continue to exercise the privilege of using non-human animals for research purposes, then he must realize that covert changes in an organism may be equally damaging to the animal as overt changes, although the former are not equally unpleasant to the human eye (Bekoff, 1976:31)

Field observations and pellet analysis are the least interventive methods of raptor food studies. Field observations include sign reading and nest observations. Red-tailed hawks regurgitate undigested prey remains (hair, feathers, scales, exoskeletons, and some bones) as pellets or "castings". These pellets can be collected under the nest-tree.

Field observations alone can be misleading (Errington, 1932). The advantages and disadvantages of pellet analysis for use in buteos have been discussed by a variety of authors: Brooks (1929); Duke et al. (1976); English (1934); Errington (1930, 1932); Fitch et al. (1946); Fitch and Bare (1978); Glading et al. (1943); Luttich et al. (1970); Orians and Kuhlman (1956); Phelan and Robertson (1978), and Seidensticker (1970). Fitch and Bare (1978: 5) observed that "many nests . . .were directly over streams, so that the feces, pellets, and scraps of food dropped into the water [which] removed some of the cues by which predators might find the nest." On the plains in Boulder County, red-tailed hawks nest in plains cottonwood trees (*Populus sargentii*) which are associated with water. Hence, food remains may be dropped into the water and lost for study.

Errington (1932:80) noted that "digestion of bones was especially pronounced in the Buteos, in fast-growing young hawks having high calcium requirements, and in most cases where soft-boned juvenile prey was eaten." Furthermore, "since hawks digest the bones of their prey more thoroughly than do owls, a smaller amount of each meal would be retained at the time of ingestion of a new meal by hawks" (Duke et al., 1976:5). This might result in the "stockpiling" of meals, thereby preventing accurate quantitative analysis. However, by relying on the undigested remains, ". . .hawk pellets provide qualitative data that may reflect food habits" (Fitch and Bare, 1978:7).

Luttich et al. followed certain guidelines for their quantitative pellet analysis. For example, "not more than one individual of a species was credited to any one pellet, unless numbers of teeth and bones indicated otherwise" (1970:192). They also were careful not to double count remains and pellets. This is of little significance if remains and pellet contents are analyzed separately or qualitatively.

Brooks (1929:222) noted that birds might not show up in pellets because ". . .raptors pluck birds very carefully as a rule, or else strip the skin and feathers off together, eating the meat only." Field observations may provide additional data in this case. Page and Whitacre (1975) estimated the number of birds consumed by counting primary feathers.

Habitat

"The red-tailed hawk has the widest ecological tolerance and geographic distribution of any buteo in North America" (USFWS, 1981:B-1). It has gained this tolerance and distribution by adapting to utilize a broad spectrum of prey (Beebe, 1974). However, red-tailed hawks appear not to choose nesting sites and territories randomly.

Red-tailed hawks establish territories in habitats which support their prey base. Territories must be in areas which can provide nutritional support for adults and presumably their young. Adamcik et al. studied red-tailed hawks in Alberta and stated that "about 50% of all nesting losses were associated with food shortage" (1979:16). Fitch et al. (1946) and Seidensticker (1970:40) observed that ". . .many red-tailed hawks hatched as young ground squirrels became available." Janes reported a high degree of fidelity to breeding territories and explained it by observing that, "even [a] relatively poor territory. . .presents an opportunity for reproduction and is therefore of considerable value" (1984a:203).

In order to compare various nesting sites and territories, it is crucial to understand habitats. Any method of habitat analysis must measure variables which influence prey habitat, prey abundance, and prey vulnerabilities. Habitat models are not population-predicting models. The remainder of this section will discuss two methods for habitat evaluation.

The United States Fish and Wildlife Service has developed a procedure that provides a numerical index which ". . .represents the capacity of a given occurrence of habitat (e.g., a vegetative stand or stream reach) to support a selected terrestrial or aquatic wildlife species" (Crumpacker and Ervin, 1982:123-124). This number is called the Habitat Suitability Index (HSI). HSI values range between 0 (totally unsuitable habitat) and 1 (optimal habitat). Specific instructions for variable measurement are not provided in the HSI description. It is assumed that the more data collected on each variable, the "better" the habitat evaluation.

An HSI model was developed to model the relationship between habitat and red-tailed hawk success for the eastern United States (USFWS, 1981). This model assumes that red-tailed hawks hunt in grasslands and nest in deciduous forests. Remote sensing methods (e.g., U.S. Geological Survey topographic maps) may be used to estimate the relative percentages of the various broad types of habitat (e.g., forest versus grassland).

Variables in each habitat are measured (APPENDIX II). Values are calculated by weighing these variables by the amount of habitat available. The lower of these two values is HSI. This "limiting-factor-concept" is crucial for a habitat analysis in the East where both habitats are used by the hawks. This feature "acknowledges" the importance of all critical variables. It prevents a habitat which lacks, or possesses limited amounts of, a crucial variable from being classified as "optimum" habitat. In Boulder County, red-tailed hawks nest in cottonwoods on the plains and in coniferous forests west of the plains. The relationship between grasslands for hunting and forests for nesting is not always present in Boulder County.

Noon et al. (n.d.) developed a method to evaluate habitat use by raptors which does not contain a limiting-factor-concept. They identified variables to be measured in forested habitats and nonforested habitats. They provided explicit instructions for its implementation. This comprehensive evaluation procedure is beyond the scope of this project and also interferes with some of the goals of this project. (It requires nest tree climbing to record certain variables. Therefore, this method is more interventive than HSI.)

Luttich et al. (1970:201) concluded ". . .that the red-tail is an extremely adaptable raptor, capable of effectively utilizing a wide variety of habitat types. Its skill as a predator. . .is evidently sufficient to permit occupation of both open and forest cover types with equal facility." Therefore, a modified HSI could be applied. This would remove the "limiting-factor-concept" while still providing a meaningful method of comparing the habitats around the nests.

Human Attitudes Toward Raptors

An understanding of human attitudes toward raptors (specifically red-tailed hawks) and how they have changed over time allows one to understand past and current methods of food habit study and also past and present management techniques. This section will discuss human attitues towards raptors and how they have changed as documented by legislation involving raptors.

"Birds of prey have been treated as enemies ever since European settlement began" (Mowat, 1984:85). "Man's hostility toward hawks and owls probably began when he questioned their right to kill and consume grouse, ducks, or any other prey that might serve as food for himself" (Craighead and Craighead, 1956:201).

Farmers and ranchers frequently found themselves at odds with predators. In the late 19th century scientists, realizing the value of certain predators in rodent control, attemped to protect some species. Management of these species has always been related to the human costs and benefits derived from them. For example, Broadbent (1971) said that:

> Historically wildlife managers have based their predator control programs on two tenets, neither of which is supported by the facts. The first is that all predators are bad and they decimate our wildlife. . . . The next is that. . .[they], the purveyors of wildlife, have an innate responsibilty to the livestock industry for any wildlife depredations on domestic animals (p. 51).

If a raptor species was said to eat chickens or game birds it was persecuted. If it ate agricultural pests, it was protected. Broadbent realized that we should value predators for other reasons (e.g., the call of a coyote is intrinsically beautiful). Now we realize that raptors can control agricultural pests, serve as indicator species, and that people value the esthetic experience of simply seeing them fly around.

As early as 1930, McAtee and Stoddard called for protection of raptors because they claimed there was not enough data to define which raptors were beneficial and which were not beneficial. Meanwhile,

> they are becoming rare enough throughout most of the United States already to need the special treatment we should have available when required for the protection of any species of wild life actually threatened with extermination. Regrettably, it is probable that before we have attained that evidence of civilization, the hawks and owls will be too far gone to profit by it (p. 19).

In 1893, Fisher (discussing red-tailed hawks) said:

> . . .its inappropriate name 'Hen Hawk' stimulates an unceasing warfare against it. The farmers, who are chiefly benefited by it, are its most pronounced enemies, because of the erroneous belief that the Red-tailed Hawk is a persistent and destructive enemy of poultry (p. 48).

Later views on the benefits and costs of red-tailed hawks to humans have been along the same line of thought; red-tailed hawks do eat some chickens and game species, but they are generally a beneficial species because they eat considerable numbers of 'harmful pests' and should therefore not be persecuted (Bailey, 1918; Criddle, 1917; Errington, 1933; Fitch and Bare, 1978; Gloyd, 1925; Hornaday, 1913; Knight, 1902; Langenbach, 1938; May, 1935; McAtee, 1935; McDowell, 1949; Mendall, 1944; Miller, 1931; Munro, 1929; Pearson, n.d.; Sage et al., 1913; Stoddard, 1931; Taverner, 1934). Errington (1933) regarded "it as being one of our most valuable wild life [sic] species and one having too low a reproductive rate. . .to hold up under the terrific persecution it receives thoroughout the United States" (p. 28). He suggested non-lethal means of behavioral modification rather than outright killing of offending birds (e.g. if a red-tailed hawk was near your chickens--shoot in the air to scare the hawk away). In 1935, May observed that red-tailed hawks were effective rodent killers and stated that they should be protected because "it is one of the species which has diminished markedly in recent years over much of its range" (p. 33).

A problem with protection of select raptor species (e.g. red-tailed hawks) was identified by Orians (1955) who, when studying red-tailed hawks in Wisconsin, observed that none of the ". . .local residents were able to or cared to distinguish one species of hawk from another. All were unanimous in saying that hawks are shot whenever possible in their area. The attitude that the only good hawk is a dead hawk still prevails" (p. 10). Therefore, he continued, legislation protecting certain species of hawks would be ineffective ". . .until public opinion is behind it." A possibility that Orians did not consider would be to protect all raptors. There would be no mistaken identifications of hawks shot if no hawks were to be be shot. Baldwin et al. (1932), prophetically realized this 23 years before when they noted that, "control measures designed to eliminate certain species and not others are distinctly and unquestionably <u>inadvisable</u>" (p. 420). They based this statement by discussing the results of the 1929, five dollar bounty in Pennsylvania on goshawks. "Within one year after the law went into effect, 503 birds were taken into the office of the Pennsylvania Game Commission at Harrisburg in order to receive the $5.00 bounty. Out of this [sic] 503 birds only 76, or 15% were goshawks. Over 58% of all birds taken were of beneficial varieties" (p. 420).

Legislation concerning raptors has been at the local, state, federal, and international levels. Legislation has included: no protection, bounties on certain species, protection of some species, and protection of all species. The most infamous of all raptor legislation was the 1885 "scalp act" in Pennsylvania. Merriam (1886:228-229) described it well.

> On the 23d of June, 1885, the legislature of Pennsylvania passed an act known as the "scalp act," ostensibly "for the benefit of agriculture," which provides a bounty of 50 cents each on Hawks, Owls, Weasels, and Minks killed within the limits of the State, and a fee of 20 cents to the notary or justice taking the affidavit.
>
> By virtue of this act about $90,000 has been paid in bounties during the year and a half that has elapsed since the law went into effect. This represents the destruction of at least 128,571 of the above-mentioned animals, most of which were Hawks and Owls.
>
> Granting that five thousand chickens are killed annually in

Pennsylvania by Hawks and Owls, and that they are worth 25 cents each (a liberal estimate in view of the fact that a large proportion of them are killed when very young), the total loss would be $1,250, and the poultry killed in a year and a half would be worth $1,875. Hence it appears that during the past eighteen months the State of Pennsylvania has expended $90,000 to save its farmers a loss of $1,875. But this estimate by no means represents the actual loss to the farmer and the tax-payer of the State. It is within bounds to say that in the course of a year every Hawk and Owl destroys at least one thousand mice, or their equivalent in insects, and that each mouse or its equivalent so destroyed would cause the farmer a loss of 2 cents per annum. Therefore, omitting all reference to the enormous increase in the numbers of these noxious animals when nature's menas of holding them in check has been removed, the lowest possible estimate of the value to the farmer of each Hawk, Owl, and Weasel would be $20 a year, or $30 in a year and a half.

Hence, in addition to the $90,000 actually expended by the State in destroying 128,571 of its benefactors, it has incurred a loss to its agricultural interests of at least $3,857,130, or a total loss of $3,947,130 in a year and a half, which is at the rate of $2,631,420 per annum! In other words, the State has thrown away $2,105 for every dollar saved! And even this does not represent fairly the full loss, for the slaughter of such a vast number of predaceous birds and mammals is almost certain to be followed by a correspondingly enormous increase in the numbers of mice and insects formerly held in check by them, and it will take many years to restore the balance thus blindly destroyed through ignorance of the economic relations of our common birds and mammals.

In 1899, 30 states had no legislation protecting any raptors (Phillips, 1949). As of 1949, at least 30 states protected "all hawks and owl, except the bird hawks--Cooper's, sharp-shinned, and goshawk--and the great horned owl " (Phillips, 1949:377). In 1972, "all species of raptors occurring in the wild in the United States and Mexico were given Federal protection under the Migratory Bird Treaty Act [16 U.S.C. 703-711]" (U.S.F.W.S., 1977:1). "Protection" means that if a human wants to trap, band, collect, kill, import, or export a raptor, a permit must first be obtained. Violations of the Migratory Bird Treaty "are punishable by fines of up to $500 and/or six months in prison, and revocation of permits if applicable. Sale or barter of raptors is a felony, punishable by a $2,000 fine and/or two years in prison" (U.S.F.W.S, 1977:5). There are stiffer fines related to bald eagles and endangered species. As with all laws, state laws do not take precedence over Federal laws unless the state law is more restrictive (U.S.F.W.S., 1977).

In Colorado, "turkey buzzards" were the only raptor protected in 1899 (Phillips, 1949). In 1903, all raptors were protected except sharp-shinned hawks (*Accipiter striatus*), Cooper's hawk (*Accipiter cooperii*), goshawks (*Accipiter gentilis*), duck hawks (*Falco peregrinus*), and great horned owls (*Bubo virginianus*) (C.S.A., C.73, § 225, 231). According to Robert Tully (pers. comm.), even though most raptors were protected by law, there was little, if any, enforcement of the law. Raptors, including red-tailed hawks were routinely killed in Colorado until the 1960s.

"'Falconry' means the sport of taking quarry by means of a trained raptor" (50 C.F.R., § 21.3). Falconry was practiced in ancient Egypt. Falconry was very popular in the Middle Ages. The more "noble" species (e.g. falcons and eagles) were reserved for the aristocracy. Falconry was introduced to America in the early 20th century (Nye, 1966). Falconry has existed as a sport in Colorado since before the 1930s (Robert Tully, pers. comm.). In 1963, Colorado passed a law requiring permits for possession of raptors (Colorado Session Law, Ch. 142, 1963). This law was one of the first laws in the United States designed to regulate falconry. Later, Colorado's falconry laws were stiffened and ultimately adopted into the Federal Regulation 50 C.F.R. 21--Migratory Bird Permits. State statutes 21.3, and 21.28-21.30, of 50 C.F.R. 21, deal specifically with raptors and falconry. It outlines a continuum of permits and levels of experience required before a falconer can obtain certain species. Wild red-tailed hawks can be taken by those falconers in the lowest class ("Apprentice"). Colorado Wildlife Commission Regulations (Chapter 6) also discusses requirements for falconry. Colorado's regulations are a little more restrictive than the Federal laws. Red-tailed hawks still can be taken by apprentice falconers.

Robert Tully (pers. comm.) said that once a falconry permit is obtained, the falconer can remove one eyas red-tail (2-3 week old juveniles are ideal) from a nest. "When a young raptor is removed from a nest at least two (2) live young raptors shall remain in the nest or aerie" (Colorado Wildlife Commission Regulations, Chapter 6, Article IIb). In practice, there is little supervision by the Colorado Division of Wildlife. A falconer is supposed to report to the local Division officer that s/he is removing a raptor from a nest at a particular location. Once reported, they are allowed to capture the raptor without the officer checking the status of the nest.

MATERIALS AND METHODS

Red-tailed hawk nests were located in early 1985. The methods of Call (1978) and Craighead and Craighead (1956) were used to locate nests. I began searching for nests on 16 January and continued until late July. Historical nests were re-checked for occupancy. Areas where there were sightings of red-tails during the nesting season were checked carefully for nests.

Once the nests were identified, regular visits were made until the young fledged or disappeared. Those nests that were easily accessible received more visits than those which required substantial hiking or driving to reach. The visits were as brief, and as far from the nest as possible to limit disturbance of the adults and/or juveniles. During the visits, observations were made on the presence or absence of adult(s); sex of adults; nest defense; hunting; feeding; young; etc. Furthermore, once the young could be seen, ages were estimated (where possible) based on comparisons with photographs in Bent (1937); Call (1978); Craighead and Craighead (1956); Finley (1905); Fitch et al. (1946); Orians and Kuhlman (1956); and Sumner (1929).

Habitat analyses were conducted following the fledging of the young. A modified Habitat Suitability Index (HSI) for the red-tailed hawk was applied to all nests where juvenile red-tailed hawks were seen. Four (N, S, E, W) 25 m line transects extended from the nest tree to measure V_1 and V_2 (Appendix II) in those areas in which the red-tails nested in "grassland" (as interpreted from U.S.G.S. topographic maps). In those areas in which red-tails nested in "forests" (U.S.G.S. map interpretation) V_4 was measured on four (N, S, E, W) 25 m line transects extending from the nest tree. V_1 and V_2 were measured by two "X's", each with 25 m "arms" in grassy habitats. Additional data were collected while measuring HSI variables: diameter at breast height (dbh) of nest tree; height of nest tree; species of nest tree; height of nest; slope of ground around the nest; and distance from the nest to nearest water. This mainly provided a means of comparing nest sites. Comparisons of the entire area utilized by a given red-tailed hawk family would have required additional transects and specific knowledge about home ranges.

Pellet analysis and the identification of nest remains were supported by unintrusive nest observations from the ground to provide information on diets during the nesting season. Pellets and nest remains were collected beneath the nests soon after the young birds fledged. Approximately one hour per nest was spent searching in and around the "white-wash" zone. Each pellet was placed in an individually labeled polyethylene bag. If few pellets and/or remains were located, and nest tree climbing was feasible, the nest tree was climbed and pellets were removed from the nest surface.

Pellets and other remains were frozen for one month to kill associated invertebrates. The pellets were then placed in individual pint ice cream containers and were allowed to reach room temperature prior to analysis.

Pellet analysis consisted of numbering, weighing, and measuring each pellet. Gross morphology was described (color, texture, the presence or absence of fur, feathers, scales, bones/teeth, odor, and moisture). The contents were then identified.

Content identification was based on the identification of fur, feathers, bones, and teeth. Useful keys and guides included: Armstrong (1972); Armstrong and Freeman (1982); Brown (1942); Gilbert (1980, 1981); Hausman (1920); Hoffmann and Pattie (1968); Mathiak (1938); Moore et al. (1974); Nason (1948); Stains (1958); Williams (1938). Road-killed small mammals were collected for comparative purposes. Zoological collections of the University of Colorado Museum were also used for comparison. Expert judgment of specialists affiliated with the University of Colorado was relied upon for identification of some contents.

Specifically, a set of comparative hair slides of locally collected specimens (when possible) was made for hair analysis. If a nest had fewer than 20 pellets, hair was identified in all of the pellets. If a nest had more than 20 pellets, hair was identified in 20 randomly selected pellets. Five percent of those pellets analyzed for hair were re-analyzed to obtain a measure of precision (# correctly re-identified/# re-identified).

Feathers were analyzed, in all pellets containing them, by Joe Strauch (an expert associated with the University of Colorado Museum). Identifications were made when possible. Scales and chitinous remains were not identified. Bones and teeth were identified when possible. Direct comparisons with the mammalian skull collection were made frequently.

Pellets were placed in one of seven mass classes (0-0.49 g, 0.5-0.99 g, etc. to >3.0 g). Pellets were also analyzed based on their kinds of contents (fur, feathers, scales, bones/teeth, more than one kind, and identifiable bones/teeth).

A list of food items of the red-tailed hawk and their source in the literature was developed. Certain criteria were followed when assembling the list. Primary sources were located. Species were listed only when it was clear exactly which species were being reported (common names confused the process). Technical and common names of mammals followed Jones et al. (1982). Hall (1982) was useful in tracking down obscure mammalian names. The A.O.U. checklist (1983) was used for common and scientific names of birds. The 1957 checklist was helpful in tracking down synonymies. Names of amphibians and reptiles follow Collins et al. (1978). Fish names follow Robins et al. (1980). Numerous sources were used to organize the invertebrates. This list was supplemented with the list generated from pellet analysis.

RESULTS

Nests

Over 6,000 miles were driven searching for and monitoring nests. Nine nests were located in 1985. Eleven additional areas were searched intensively for nests. Nesting results are summarized on Table I. Once nests were located to determine progress, I made more than 113 visits (range 1-26) to the nesting areas. Ninety percent of the observed pairs of hawks laid eggs. Incubation began as early as March (Nest #4). The young fledged from late May (Nest #4) to mid-July (Nest #6). Nine to fifteen juvenile red-tailed hawks fledged (an average of 1-1.7 hawks per nest). Descriptions of the nests and their approximate locations follow. Life requisite values of each of the nests and the species of the nest tree are summarized on Table II.

NEST # 1--WILD BASIN-84 (40°13'N, 105°32'W)

This nest was a few hundred meters NE of Wild Basin-85. It was aproximately 2550 m above sea level in an Upper Montane forest (Marr, 1964). Because no young were seen in it, a habitat analysis was not conducted. The habitat was similar to that of nest # 6 (Wild Basin-85).

NEST # 2--BOULDER VALLEY RANCH-85 (40°04'N, 105°15'W)

This nest was located 12.5 m up a plains cottonwood tree in a large, gently rolling (angle <5°) horse pasture at Boulder Valley Ranch. The horse pasture formerly contained a substantial prairie dog colony. The colony was poisoned in 1981 with strychnine. Neighboring (less than 1 km away) prairie dog towns remain. A few prairie dogs were seen within 100 m of the nest in June. The hawks built this nest in 1984 (Jones, pers. comm.). From at least 1982 until 1984, the hawks nested over Farmers Ditch, about 250 m from this nest. There was an active great horned owl (*Bubo virginianus*) nest about 1 km away from the 1985 nest. The nest tree was aproximately 1630 m above sea level in the Plains Grassland region (Marr, 1964). The nest was aproximately 215 m from the nearest water source (Farmers Ditch). The tree was 26.2 m high and had a dbh of 1.17 m. The HSI of the area, calculated from four "grassland" transects, which measured food variables, on 16 August 1985, was 0.61.

NEST # 3--41st & OXFORD (40°07'N, 105°15'W)

This nest was built in 1985 following a successful theft of the 1984 nest by great horned owls. The usurped nest was in the same small woodlot, less than 75 m away from the active hawk nest. The elevation of the nest tree was 1646 m also in the Plains Grassland region (Marr, 1964). The nest was directly above an irrigation ditch and next to a small irrigation pond. Mostly overgrazed cow pastures surround the nest. The unflooded pasture below the nest contained a small prairie dog colony. Red-winged blackbirds (*Agelaius phoeniceus*) nested around the pond. The hawk nest was 17.6 m high up a 22.4 m tree with a dbh of 0.55 m. The HSI of the area was calculated by measuring "grassland" and "forest" variables since the woodlot was identifiable on a U.S.G.S. map. The life requisite values were 0.1 (food), and 1.0 (reproduction) measured, in both the "forest" and the "grassland," on 20 August 1985. Without the "limiting-factor-concept", the HSI was 1.0.

NEST # 4--WEISER (40°03'N, 105°09'W)

This nest was one of several red-tailed hawk nests in the immediate area, presumably constructed by the same pair (Weiser, pers. comm.). It was located on the edge of a flat woodlot, above an irrigation ditch, less than 1 km from Boulder Creek. A large, uncontrolled prairie dog colony was less than 1 km from the nest. The woodlot was surrounded by well-managed cow and horse pastures. In the horse pasture, prairie dogs were controlled by shooting and by having their holes filled in. The nest was about 1.5 km from nest # 8 (White Rocks). The neighboring Boulder Creek riparian zone was managed by removing beavers and keeping people out. The nest was 14.9 m up a 19.9 m plains cottonwood with a dbh of 0.88 m. The nest tree elevation of about 1550 m placed it in Marr's (1964) Plains Grassland Region. The life requisite values, calculated by measuring food variables in the grassland, was 0.97 on 21 August 1985. The HSI was 0.97.

NEST # 5--103 & 72 (40°06'N, 105°29'W)

This nest was located 19.6 m up a 26.9 m tall lodgepole pine, 2725 m above sea level in an Upper Montane forest (Marr, 1964). The ground was sloped at 7° around the nest. The nearest clearing was the intersection of State Road 72, and County Road 103. A small stream flowed beside Route 72. The nest was 0.2 km from this water source. There was much evidence of pine squirrel (*Tamiasciurus hudsonicus*) activity in the forest around the nest. The grassy areas surrounding the intersection contained sign of montane voles. An active great horned owl nest was less than 1.5 km SE of the red-tailed hawk nest. The dbh of the nest tree was 0.53 m. The life requisite values based on food (0.0) and reproduction (0.24) were measured in both the "forest" and the "grassland" on 28 August 1985. Ignoring the "limiting-factor-concept," the HSI was 0.24.

NEST # 6--WILD BASIN-85 (40°13'N, 105°33'W)

This nest was 21.9 m up a 22.9 m tall ponderosa pine with a dbh of 0.7 m. The ground around the nest was steeply sloping (35°). The nest tree was aproximately 2550 m above sea level in a thinly wooded, Upper Montane forest (Marr, 1964).

The valley below the nest contained the meandering North St. Vrain Creek with its associated riparian ecosystems. The nest was aproximately 0.4 km from the nearest body of water. Many bird species nested in the area around the creek. Abert (*Sciurus aberti*) and pine squirrels were common on the slopes around the nest. The life requisite values were calculated by measuring food (0.7) and reproduction (0.7) variables in both the "grassland" and the "forest" on 28 August 1985. The HSI was 0.7.

NEST # 7--MATRON (39°56'N, 105°17'W)

This nest was located east of the Matron, a rock formation about 2010 m above sea level. The nest was 15.8 m up a 19.9 m ponderosa pine with a dbh of 0.62 m. The Mesa Trail runs in the grassy valley east of the nest which was located in the Lower Montane Forest (Marr, 1964) adjacent to a large talus slope. The nest was 0.6 km away from the nearest water source (the creek running through Shadow Canyon). There was substantial vole activity in the grassy areas adjacent to timberline. The HSI of the area was calculated from the life requisite values for food (0.4), and reproduction (1.0), measured in the "forest" and in the "grassland" on 19 August 1985. Disregarding the "limiting-factor-concept," the HSI was 1.0.

NEST #8--WHITE ROCKS (40°03'N, 105°08'W)

This nest was less than 1.5 km east of nest # 4 (Weiser), 1545 m above sea level, in Marr's (1964) Plains Grassland Region. Large ponds, periodically rich with waterfowl, and cattle-grazed meadows surrounded this nest. It was 24.5 m up a 33.1 m plains cottonwood with a dbh of 1.19 m. The trunk of the nest tree was less than 6 m from a bend in Boulder Creek. The nest was less than 100 m from an expanding prairie dog town. An active great horned owl nest was less than 1 km S of the hawk nest. An HSI of 0.6 was calculated by measuring food requisites for the "grassland" surrounding the nest on 22 August 1985.

NEST # 9--35th & NIMBUS (40°06'N, 105°16'W)

This nest was located in a small stand of trees near an irrigation ditch, in a lightly grazed cow pasture, 2010 m above sea level. Since no young were raised at this nest, no habitat analysis was conducted.

NEST # 10--OUREY (40°09'N, 105°13'W)

This nest was located in a small stand of trees near an irrigation ditch, about 1585 m above sea level. Cattle and horses grazed the pastures surrounding the nest tree. A habitat analysis was not conducted because the nest was abandoned.

NEST # ?-49th & LEFTHAND (@40°06'N, @105°14'W)

This nest probably was located in a woodlot near Lefthand Creek. The meadows around it were frequently overgrazed. The meadow west of it, along Lefthand Creek, had a dense colony of prairie dogs living in it. A habitat analysis was not conducted as the nest never was located.

Food Habits

Food data were collected from nests 1-8. Pellets were collected beneath all nests except nest # 7 (Matron). The # 7 nest tree was climbed to reach the nest. About 30 minutes was spent inside the nest removing pellets and some remains from the top layer of material. The nest was not destroyed while gathering information. The breakdown of the pellets by mass group is presented in Table 3 and Figure 1. The numbers of pellets collected from each nest is illustrated in Figure 2. The number of pellets collected from each nest varied greatly (2 to 147). The kinds of contents in the pellets are presented in Table 4 and Figures 3-8. Most pellets contained fur (Fig. 3). Most nests had pellets containing feathers in fewer than 20% of the pellets collected. A notable exception was nest # 3 (41st & Oxford) which had feathers in 67% of its pellets (Fig. 4). Forty-eight percent of the pellets collected contained scales. The scales were not distributed evenly among the nests. Nest # 2 (BVR) had scales in none of its pellets, while nest # 7 (Matron) had scales in 69% of its pellets (Fig. 5). Bone and teeth remains in pellets also varied. Thirty-six percent of the pellets collected had bone, tooth parts, or fragments. However, nest # 4 (Weiser) had bones or teeth in 74% of its pellets whereas nest # 2 (BVR) had them in none (Fig. 6). The more pellets containing bones or tooth parts collected from a given nest, the smaller the percentage of identified bones or tooth parts (figs. 2 and 7). Seventy percent of those pellets collected contained more than one kind of food item (Fig. 8). However, nest # 2's (BVR) pellets only contained one kind each while every pellet in nest # 1 (Wild Basin-84) contained at least two kinds of contents.

The results of the literature search for food habits of red-tailed hawks are listed in Appendix III. Thirty-nine orders, 176 genera, and at least 247 species have been said to be consumed by red-tailed hawks. In the present study, at least 31 species of mammals from four orders were identified by nest remains, hair, bone, or tooth analysis (Tables V and VI). Eighty-two percent of those hair samples analyzed were correctly re-identified. Seven of the species (*Castor canadensis, Ochtona princeps, Cynomys ludovicianus, Geomys bursarius, Microtus longicaudus, Reithrodontomys montanus, Tamias umbrinus*) had never been reported to be consumed by red-tailed hawks. Six avian species were identified from feather analysis (Tables 5 and 6).

DISCUSSION

Productivity

The numbers of pairs of hawks laying eggs (90%, n = 10), compared favorably with what has been reported in the literature (90%, n = 650). Unlike the observations of Craighead and Craighead (1956), Hagar (1957), Luttich et al. (1971), and Seidensticker and Reynolds (1971), most (3/4) of those red-tailed hawk nests near (≤1.5 km) great horned owl nests produced at least 2 young per nest. It is possible that the BVR nest failed because of owl predation on the young.

Seidensticker and Reynolds (1971) listed several reasons why red-tailed hawk nests might fail to produce young. It is possible, but not probable, that my observations might have influenced nest successes. My visits did not include nest tree climbing and were as brief as possible. However, other humans could have influenced nest failure. Gunshots were heard in the vicinity of nest # 5 (103 & 72). A Boy Scout camp was nearby. Additionally, the nest was visible from the road. Visits could have attracted the attentions of others who might have removed or killed the young. A close investigation for signs of climbing spike use on nest # 5 tree proved fruitless. Adamcik et al. (1979) noted that about 50% of the nesting losses of young red-tailed hawks was due to food shortages. Other natural effects leading to nest failure cannot be discounted. For example, nest # 10 was blown out of a tree at least twice before being abandoned.

Henny and Wight (1972:245-246) estimated that ". . .1.79-1.89 young [red-tailed hawks] must be fledged per breeding-age female to maintain a stable population" south of the 42nd parallel. In Boulder County, 1.0-1.7 red-tailed hawks fledged from those located nests. These numbers seem low. However, all nests located were analyzed, not a random sampling of nests. Average success from hatching to fledging of hawks in Boulder County (60%, n = 10) compared favorably to that reported in the literature (64%, n = 123). This study was only one year long. Too few data were collected to allow definitive statements about population trends in Boulder County.

The lengths of the breeding seasons of red-tailed hawks in Boulder County seemed low (ca. 46 - ca. 83 days) compared to the approximately 112 days (range 79-141) reported in the literature. I had difficulties assessing the status of the nesting season from the distances that most nests were observed. Previous studies had used more interventive techniques (e.g., regular nest-tree climbing) and therefore had collected more precise data. However, nest # 3 (41st and Oxford) was observed closely. A 46- to 49-day nesting season (incubation to fledging) was seen at this nest. Therefore, the possibility exists that those numbers reported in the literature are somewhat high, or that red-tailed hawks exhibit remarkable flexibility in length of breeding season.

Habitat Analyses

The fact that red-tailed hawks nested in areas with such variable HSI's, shows that my habitat assessment methods might be at fault or that the proper variables were not measured. Numerous samples over several years, not just a few samples on a given day, might have better described the habitats around the nests. Also, home range information would have allowed additional representative transects. However, preliminary generalizations can be made. Red-tailed hawks nest high up in large trees, fairly close to water, and sometimes above or near a concentrated food source (e.g., a prairie dog town). Height probably serves to avoid predators and also to gain a good overview of the surrounding area. (When I was in the Matron nest collecting pellets and remains, I could see for miles in most directions.) Water might be required for prey abundance or nest tree growth. Nests were only directly above a water source on the plains. Since cottonwood trees require water, this is not unusual. I do not think (as did Fitch and Bare, 1978) that red-tailed hawks choose nests above bodies of water "so that the feces, pellets, and scraps of food [are] drop[ped] into the water [to] removed [sic] some of the cues by which predators might find the nest" (p. 5). I had few problems collecting pellets beneath nests. Nest sanitation (as Orians and Kuhlman, 1956, reported) is probably conducted by removing uneaten prey from the nesting area. Nesting above or near a concentrated food source probably reduces the costs of foraging.

While HSI is <u>not</u> a population predicting model, it is interesting to see the relationship between HSI and nesting success. When HSI's "limiting-factor-concept" was ignored, the results were less than telling. A relatively high life requisite value did not guarantee producing more young than a low value (nest #8, White Rocks, produced two young with a value of 0.6, wheras nest #3, 41st and Oxford, probably produced two young with a value of 1.0). The nest with the lowest value (nest #5, 103 & 72, value = 0.24) probably produced no young. These data showed little relationship between HSI and nesting success although the sample size is too small to be predictive.

Prey Items and Methods

> What a redtail [sic] or any other Buteo [sic] eats is largely a matter of what is to be had without too much trouble; what is conspicuous enough to be readily seen by a hungry bird; what is within the bird's power to capture and to handle; or what is already available in the form of a carcass beside a highway, along a lake shore, or in a field or a woodlot. The feeding of all mid-west Buteos upon rodents, snakes, invertebrates, and whatever else they may recognize as eligible food and can readily get claws on, reveals a conforming to ecological pattern that combines, as well as is controlled by, the elements of naturalness and necessity (Errington and Breckenridge, 1938:121).

The prey species identified from each nest were species expected to be found in the vicinity of each of the nests. Bent (1937:157-158) stated that ". . .the young [red-tailed] hawks are fed largely on [sic] mice and squirrels." "Squirrel-sized" mammals seemed to be present as remains wherever they were found. Also, chipmunk- and mouse-sized mammals were consumed.

Bird remains were found in pellets at a low, but fairly consistent rate. Most feathers were not identifiable. "Flicker-sized" birds were represented from most nests although red-tailed hawks have been known to eat all but the largest species. No bird remains were found in nest #1 or #2. This could indicate those individuals not hunting birds or it might be an artifact of the small numbers of pellets collected from each of those nests. Bent (1937:157) noted that "probably most of the small birds are killed during the nesting season as food for the small young."

Reptiles and amphibians were not identified, but probably were preyed upon whenever possible. Hammerson (1982) listed amphibians and reptiles found in

Colorado and where they are found. Amphibians probably left few identifiable remains. None of the scales appeared to be fish scales. I do not think that scales in pellets represented individual prey items or individual meals. The large percentage of pellets containing scales was probably caused by the scales lying around the nest and either becoming attached to fresh prey items or becoming attached to the pellets after they were regurgitated. Another possible cause for the large numbers of pellets containing scales might be that scales are not regurgitated as easily as fur. This might produce a 'reservoir' of scales in a hawk's stomach which would be regurgitated along with other items (e.g., fur, feathers). Quantitative statements about predation of red-tailed hawks on reptiles and amphibians might be misleading.

Invertebrate remains were not noted or identified. Whereas red-tailed hawks may opportunistically prey on some invertebrates (e.g., grasshoppers), some invertebrates might become associated with a pellet after the hawk has regurgitated it. The list of invertebrates associated with red-tailed hawks should be considered in light of the fact that it is impossible to determine the origin of many invertebrates (the hawk may have eaten the invertebrate directly, or the invertebrate might have been inside the mouth or stomach of a vertebrate consumed by the hawk, or perhaps the invertebrate was eating a pellet).

Bone and tooth fragments were generally of no use in identifying remains. Entire jaws, when found, proved extremely helpful. Errington (1932) was correct when he observed buteos digest most bones.

These results illustrate the problems associated with quantitative studies of the food habits of red-tailed hawks which rely on pellet analysis. Pellet analysis is the least interventive method of raptor food study if pellets are collected following fledging or abandonment of nests. However, pellet contents may not reflect individual meals and few identifiable bones are regurgitated. Qualitative studies, such as this one, must provide information on food habits of red-tailed hawks.

Future investigators should be aware of the difficulties associated with hair analysis. Korschgen (1980:115) said that "attitudes and work habits of the investigator have great bearing on achievements from food-habits studies. . . .[The investigator] must be thorough, patient, and persevering [sic]. . .". Some species' hair microscopically resembles other species' Therefore, some measure of precision should be reported for hair analysis. By having a good idea of which mammalian species live in an area where pellets were collected, thus producing a subset of hair for comparison, considerable time can be saved. Red-tailed hawk pellet analysis would not be a good mammal sampling technique.

The following discussions are about those prey species never previously reported to be consumed by red-tailed hawks.

Pikas (*Ocotona princeps*) were identified in two nests. Pikas probably were never before reported as a prey item because no previous studies had nests near timberline in an area where pikas lived. Pikas are found only in alpine talus slopes. This suggests that hawks were travelling a considerable distance (perhaps as far as 10 km by nest #5's hawks) to hunt the pikas. Pika's elaborate alarm calling system would seemingly make them less vulnerable to aerial predation than some other diurnal small mammals.

Although Knight (1902) and Lloyd (1887) reported "prairie dogs" as part of the diet of red-tailed hawks in Wyoming and Texas, "black-tailed prairie dogs" (*Cynomys ludovicianus*) had never before been specifically reported. Full-grown prairie dogs might be too large for a red-tailed hawk to fly with, but juvenile prairie dogs would pose no such problem. Prairie dogs dispersed from their coteries in the summer and were killed (in mass) by cars. Red-tailed hawks could have been scavenging these remains (they have been known to scavenge before--in 1981, a red-tailed hawk was found dead near a prairie dog burrow in the BVR prairie dog town poisoned with strychnine--Jones, 1983). At least four nests were within 1 km of active prairie dog towns. Black-tailed prairie dog remains were found in three of those nests. Clark et al. (1982) ran a large belt transect as part of a study of vertebrates associated with prairie dog colonies. In areas where black-tailed prairie dog ranges overlaped with red-tailed hawk ranges, they did not notice red-tailed hawk and black-tail prairie dog associations. Yet, my data show that black-tailed prairie dogs are part of red-tailed hawk diets when found sympatrically (3/4 of nests which were sympatric with prairie dogs showed evidence of prairie dog predation).

The management implications of this are troublesome. Prairie dogs, considered agricultural pests, are controlled by poisoning and shooting. Secondary poisons, such as strychnine, have been used routinely. Lead shot can act like a secondary poison by ultimately or directly killing an animal (e.g., a raptor) which unsuspectingly eats an animal previously shot. Other poisons (e.g., phostoxin) are indiscriminate killers, killing everything living in a prairie dog burrow (e.g., burrowing owls, snakes, ferrets, badgers). The Boulder County Extension Office issues phostoxin (with the proper E.P.A. license), gas cartridges (containing sulpher and sodium nitrate--which also kill everything in the burrows), and strychnine (strychnine has not been sold for about two years since the other methods are more effective). Non-secondary, and directable poisons are available, e.g. zinc phosphide (Tietjen, 1976). The City of Boulder has used zinc phosphide successfully for several years and (as of early 1986) was trying to have it accepted by Boulder County as the official poison. The only problem with zinc phosphide is that its application is fairly labor intensive.

Beavers (*Castor canadensis*), another species never before reported, were only consumed in the mountains. Numerous beavers used to live around the Weiser/White Rocks nests (#4 and #8) and probably were consumed there too. Those beavers were trapped and killed because of their destruction of cottonwood trees along Boulder Creek. Small beavers fall within the size-range of prey of red-tailed hawks.

Northern pocket gophers (*Thomomys talpoides*) had been previously reported as part of the diet of red-tailed hawks but plains pocket gophers (*Geomys bursarius*) had not. Plains pocket gophers were consumed at three of the plains nests in this study. All of the nests were in agricultural areas where irrigation and cultivation could have forced individual pocket gophers above ground, thus increasing their vulnerability to predation. Caldwell (1986) recently reported red-tailed hawks flying away from tractors plowing fields rather than staying around and hunting. Nevertheless, small mammals, including plains pocket gophers, are displaced by plowing and are therefore potentially more vulnerable to hawk predation.

Long-tailed voles (*Microtus longicaudus*) had never been previously reported to be consumed by red-tailed hawks. In this study, remains were identified at the Matron nest (*7). Armstrong (1972:240) noted, "the long-tailed vole occurs widely in the western United States and adjacent Canada. . ." and ". . . is the most euryecious of Coloradan microtines. . . ." One might assume that such a wide-ranging species would be consumed by red-tailed hawks wherever they were found together. Perhaps since long-tailed voles are less dependent on grass runways than other microtines and may therefore live in forested areas (Armstrong, 1972), they are more difficult to locate and catch than other species.

Plains harvest mice (*Reithrodontomys montanus*) had never been previously reported to be consumed by red-tailed hawks. This nocturnal species occupies drier areas on the plains than western harvest mice (*Reithrodontomys megalotis*) (Armstrong, 1972). Plains harvest mouse remains were identified at the White Rocks nest (* 8). As the habitats are similar, they also are probably consumed at the Weiser nest (* 4).

Uinta chipmunks (*Tamias umbrinus*) were never before reported to be eaten by red-tailed hawks. In this study, Uinta chipmunks were consumed at the nest * 5. Uinta chipmunks are found in lodgepole pine forests. Since other species of chipmunks have been reported to be consumed by red-tailed hawks, previous studies of red-tailed hawks diets probably did not occur in lodgepole pine forests where the hawks' could have captured Uinta chipmunks.

Future Studies and Management

Red-tailed hawks are fairly common raptors in Colorado. This provides an opportunity to collect considerable baseline data, and to monitor their progress in the future. Future studies should note distribution and abundance, food habits, and breeding ecology. Since the Colorado Division of Wildlife has little non-game funding, volunteers could be utilized for this research. This section will outline a potential management plan for red-tailed hawks in Colorado.

A part-time volunteer coordinator from the DOW could be appointed. Duties would include stimulating interest among local Audubon Societies, nature associations, environmental groups, and university students. Data analysis, and writing regular reports to those involved in the project would also be done by this person.

Changes in Christmas bird count data over time could be compiled by those organizations which reported the data. The coordinator could then map the results to develop abundance patterns. Bock and Lepthien (1976) cautioned that since field identification is not always correct, maps, while not providing "exact distributional limits", could be used to depict "overall abundance patterns."

The same organizations responsible for the Christmas count data could stimulate members to participate in breeding season counts. These counts would provide information on potential nest locations. For example, the Boulder County Nature Association has identified at least 36 areas in Boulder County which may have red-tail hawk nests. Most of these areas were searched for the hawks and/or nests for this study. Undoubtedly, with more people searching, more nests would have been located. Therefore, potential nest areas could be investigated by diligent members of these organizations. Information on location of nests would be restricted to as few members as possible. An emphasis on non-interventive methods would be stressed to all involved in this stage.

Once nests are located, several non-interventive checks could be made to determine nesting progress. Approximate fledging dates are easier to collect than hatching dates. Fledging dates would be particularly useful since they would "define" the nesting season.

Pellets and other remains could be collected under nests after the young fledged or the nests were known to be abandoned. Pellets could be analyzed by biology students, with the help of their instructors, at universities. The analysis need not be that rigorous. Any information on species consumed would be useful.

There would be a considerable time-lag between data collection and analysis with this many volunteers involved. However, the data would still be collected and analyzed.

With this mass of data, concrete management plans could be developed. While the red-tailed hawk is just one predator, other species rely on their prey items too. Emphasis might be placed on eliminating the use of secondary poisons (e.g., used to control prairie dogs and coyotes). Falconers might be discouraged from removing eyases from certain areas and encouraged to remove young from other areas. With known numbers of young in a nest, Colorado Wildlife Regulation Chapter 5, Article IIIb (which specified at least two young raptors remain in a nest where one was removed) might be able to be followed (In this study, only 2 of 6 productive nests might have fledged three young. If these data are representitive for Colorado, the collection of red-tailed hawks for falconry might have to be severely limited). The habitats of red-tailed hawks and their prey could be monitored. This study has demonstrated that, in Colorado, red-tailed hawks nest in a variety of habitat types.

The data collected now, while the red-tailed hawk is still fairly common, could be useful in the future if and when it becomes threatened or endangered. Regardless of the future of the red-tailed hawk, long-term data are infrequently collected because costs of collecting these data are great. This program would maximize the amount of data collected while minimizing the costs. (Of course once these data were collected management policies should be based on them. Presently, annual falconry reports are compiled, filed, and lost!) Additionally, public interest about wildlife might increase (thereby generating more non-game revenues) if the project received enough favorable publicity. The State of Colorado, and the Division of Wildlife would have a lot to gain and little to lose by embarking on such a project.

Figure 1. Number of pellets from each mass class collected at each of the nests. Number of pellets collected is plotted on the ordinate. Mass classes (Table 3) are plotted on the abscissa.

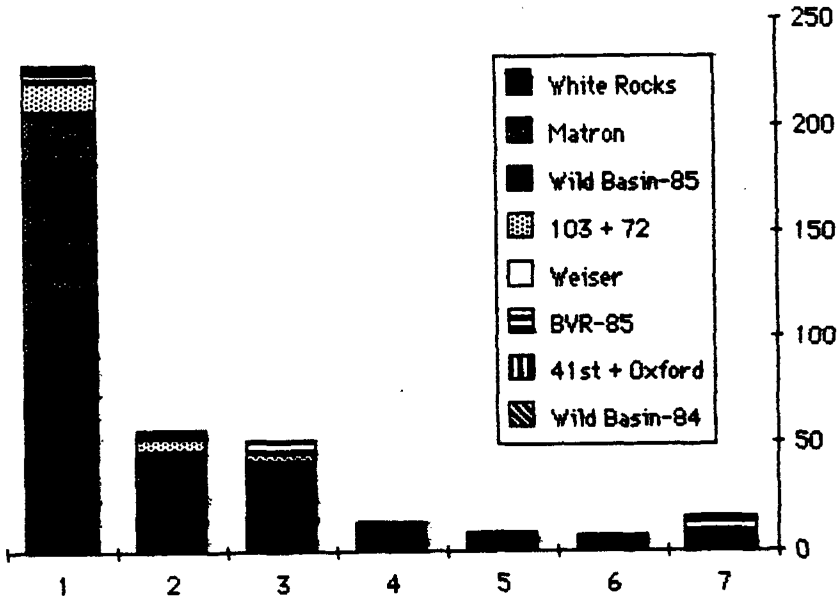

Figure 2. Number of pellets collected from each nest.

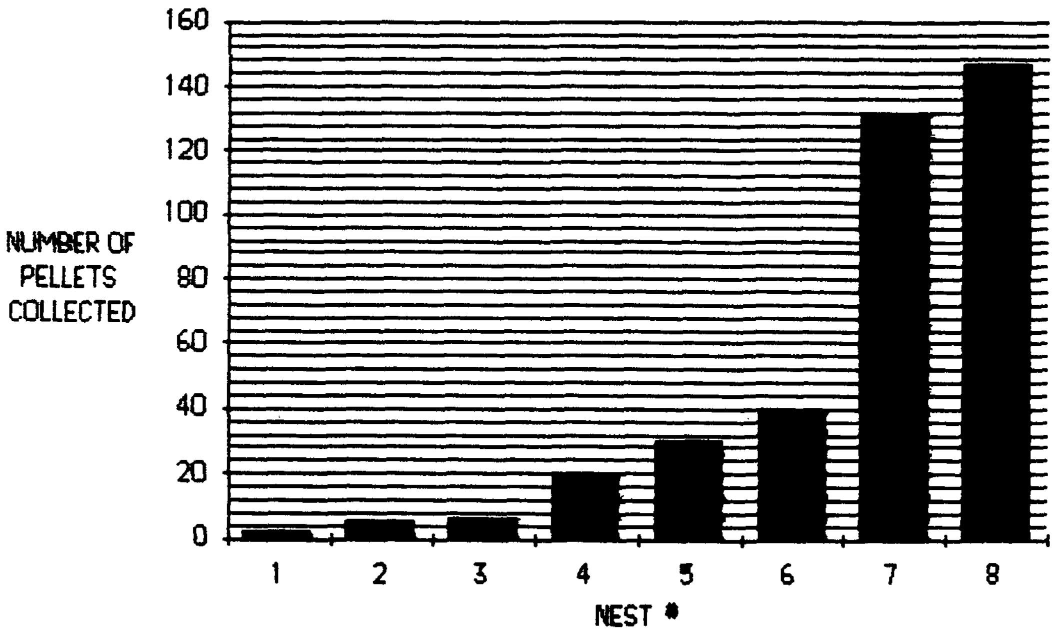

Figure 3. Percentage of pellets from each nest containing fur.

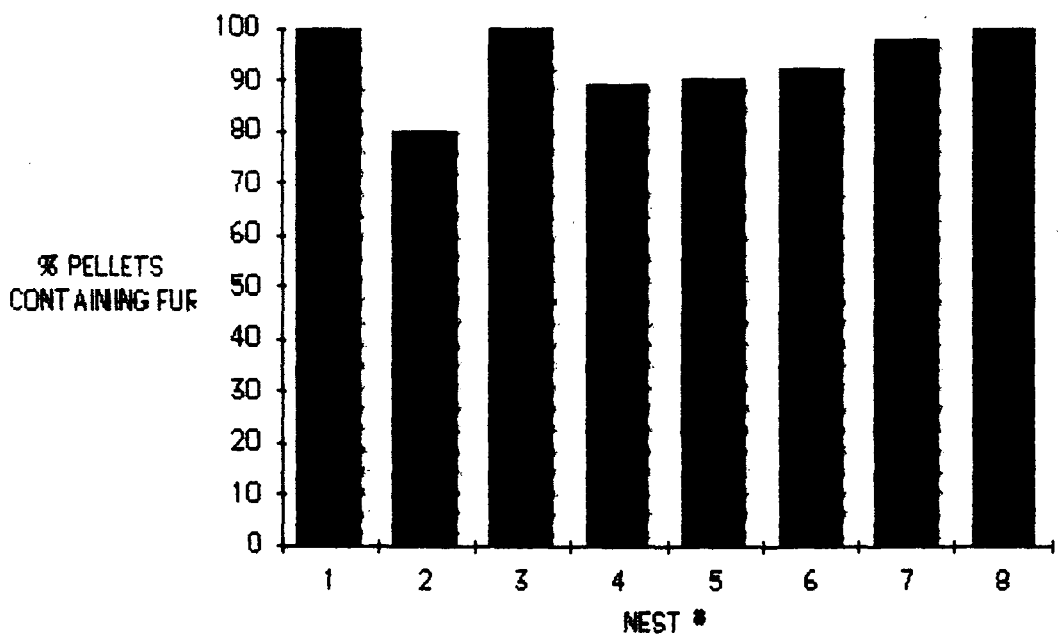

Figure 4. Percentage of pellets from each of the nests containing feathers.

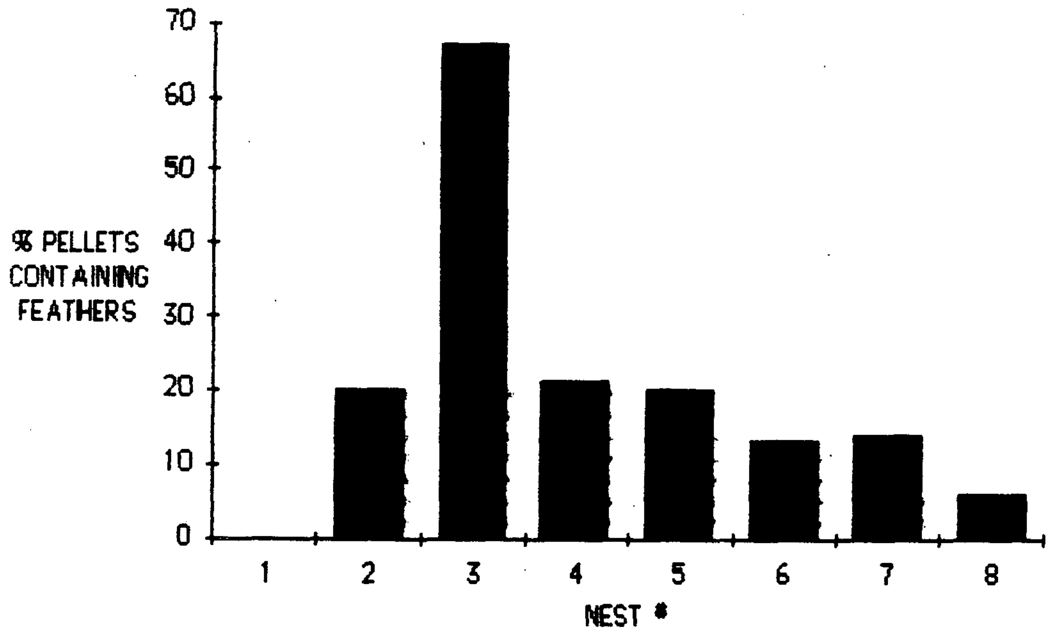

Figure 5. Percentage of pellets containing scales from each nest.

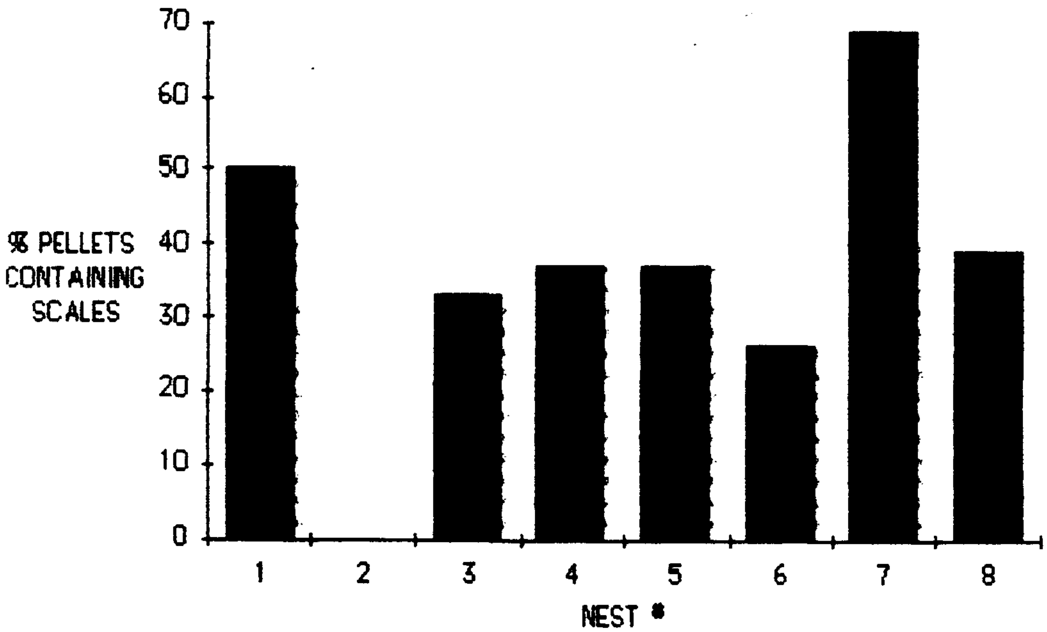

Figure 6. Percentage of pellets from each nest containing bones or teeth.

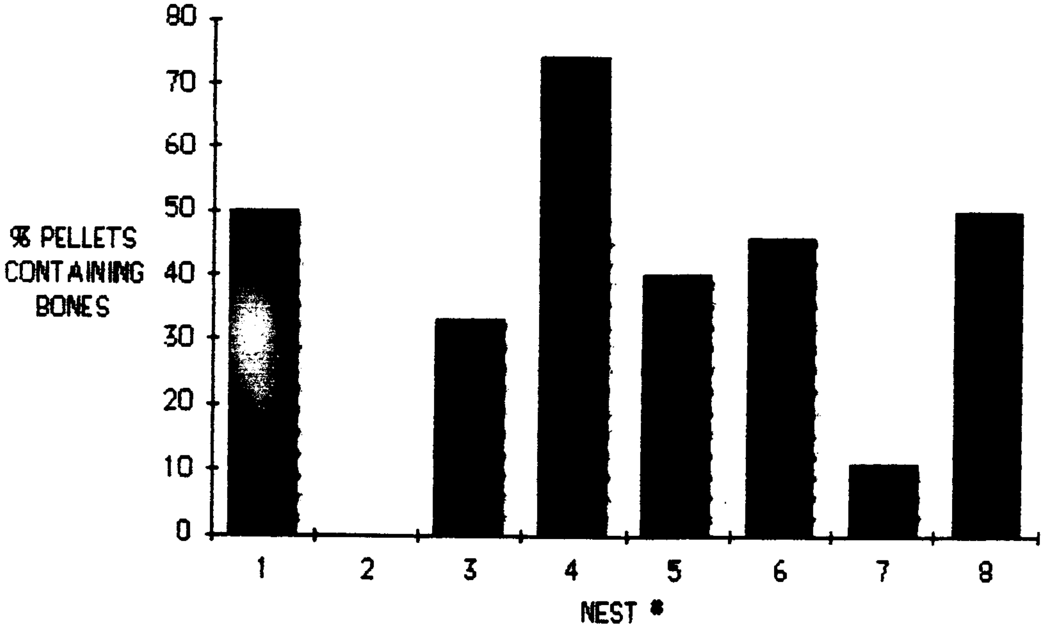

Figure 7. Percentage of bones extracted from pellets from each nest, identified to genus and to species.

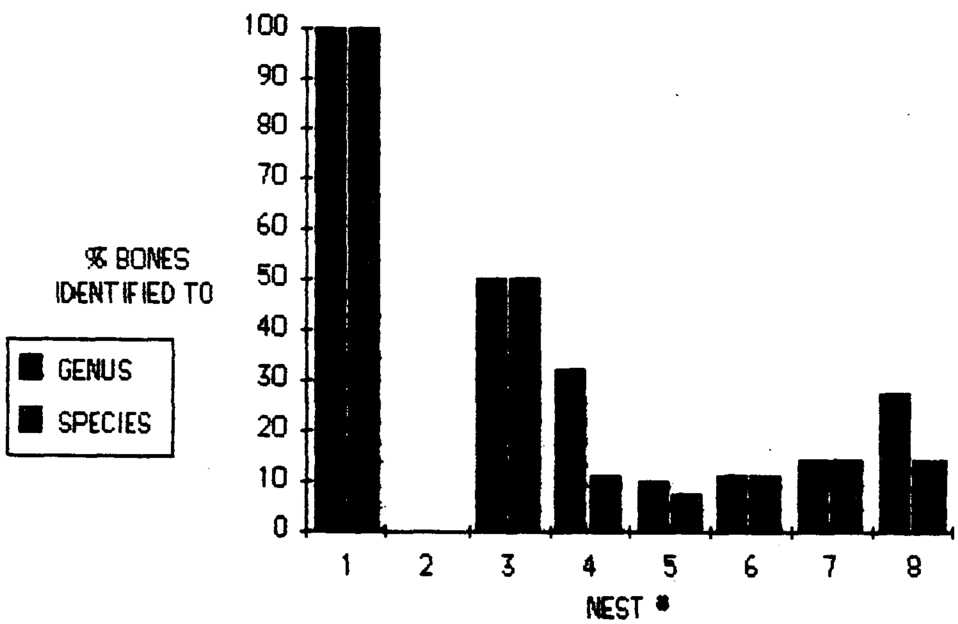

Figure 8. Percentage of pellets containing multiple food item-types from each nest.

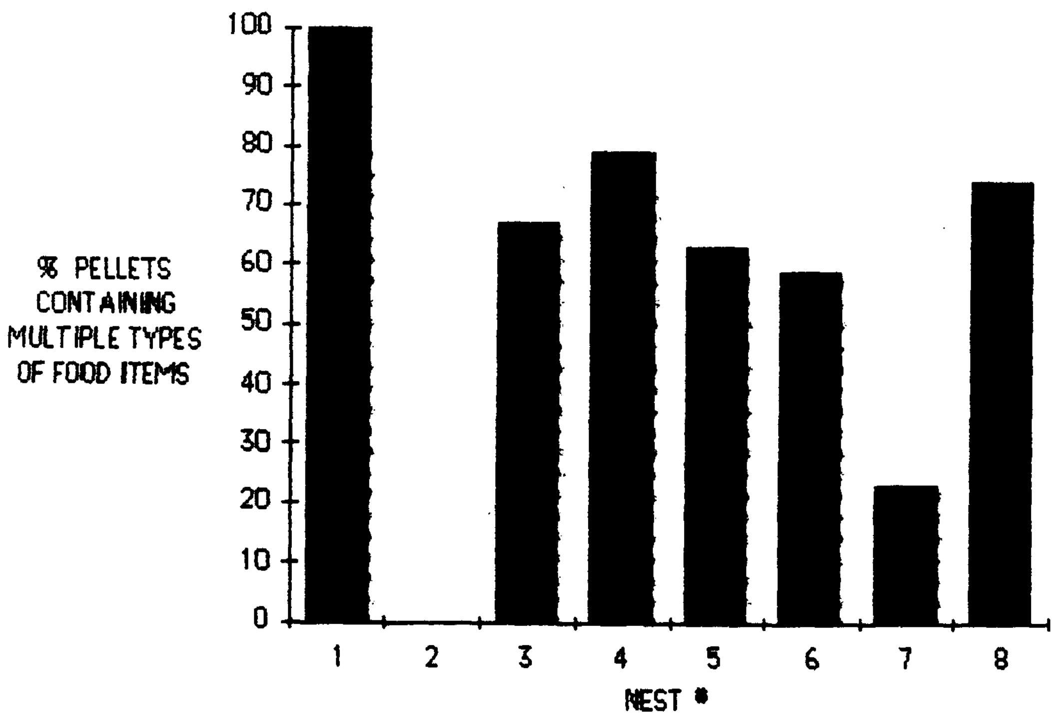

Table 1. <u>Summary of nesting chronology and productivity of red-tailed hawk nests in Boulder County during the 1985 nesting season</u>.

NEST (#)	INCUBATION	BROODING	FLEDGING	NUMBER FLEDGED
BVR (2)		<7 April-29 May	?[1]	?
41st + Oxford (3)	7 April-	≤14 May-	28 June-1 July	2[2]
49th + Lefthand (?)			>26 May	2[3]
Matron (7)	<9 April-		19-27 June	1[4]
Ourey (10)	20 March + 11 April[5]			
103/72 (5)		24 June-1 July	?[6]	?
35th + Nimbus (9)[7]				
Weiser (4)	<8 March	<17 April	<29 May	2[2]
White Rocks (8)	<9 April-			2
Wild Basin (6)	<6 June		15 or 16 July	2

[1]No activity seen on or around nest after 29 May. Nest presumably failed.

[2]Nest may have fledged three.

[3]Nest never found. Adults seen acting territorially on numerous occasions and two juveniles seen flying with adults on this date.

[4]Nest may have fledged two.

[5]Nest apparently blew out of tree twice; rebuilt first time but not second. Hawks seen in area 27 April. No new nest found.

[6]At least one downy juvenile head seen on 24 June and part of one head seen on 1 July. No hawks or activity seen after 1 July; nest presumably failed.

[7]Nest constructed late February and March; hawks seen in area through 5 April. No hawks or nesting activity seen after 5 April; nest presumably abandoned.

Table 2. Habitat analyses for red-tailed hawk nests in Boulder County, 1985.

	Life Requisite Values		
NEST #	"grassland"	"forest"	Nest Tree Species
2	0.61	-	Plains Cottonwood
3	0.1	1.0	Plains Cottonwood
4	0.97	-	Plains Cottonwood
5	0.0	0.24	Lodgepole Pine
6	0.7	0.7	Ponderosa Pine
7	0.4	1.0	Ponderosa Pine
8	0.6	-	Plains Cottonwood

Table 3. Number of pellets from each mass class collected at each nest. Pellet masses are in grams.

Nest #	Pellet Mass Groups						
	1	2	3	4	5	6	7
	0-0.49(g)	0.5-0.99	1.0-1.49	1.5-1.99	2.0-2.49	2.5-2.99	>3.0
1	0	1	0	0	0	1	0
2	2	1	1	0	0	0	1
3	1	1	0	2	1	0	1
4	4	1	6	0	1	2	5
5	15	7	4	0	3	0	1
6	24	8	5	1	1	0	0
7	92	11	22	5	0	0	2
8	90	27	14	5	2	4	5
n (Σ**n**=380)	228	57	52	13	8	7	15
n/Σn (%)	60.0	15.0	13.7	3.4	2.1	1.8	3.9

Table 4. Contents of red-tailed hawk pellets collected beneath Boulder County nests in 1985.

NEST	$\Sigma_{pellets}$	n_{fur}	$n_{feathers}$	n_{scales}	n_{bones}	n multiple contents	$n_{identifiable}$ bones
1	2	2	0	1	1	1	2
2	5	4	1	0	0	0	NA
3	6	6	4	2	2	4	1
4	19	18	4	7	14	15	9
5	30	27	6	11	12	19	5
6	39	36	5	10	18	23	2
7	132	129	18	92	14	96	3
8	147	147	9	58	74	109	34

Table 5. Mammalian and avian species consumed by red-tailed hawks in Boulder County, Colorado. Species marked with an asterisk had never previously been reported to be consumed by red-tailed hawks.

MAMMALS

ORDER INSECTIVORA

Sorex spp.

ORDER LAGOMORPHA

Lepus californicus
Ochotona princeps*
Sylvilagus audubonii* (found only by bones, not hair)
Sylvilagus nuttalii
Sylvilagus spp.

ORDER RODENTIA

Castor canadensis
Cynomys ludovicianus*
Geomys bursarius*
Marmota flaviventris
Microtus longicaudus* (found only by bones, not hair)
Microtus ochrogaster* (found only by bones, not hair)
Microtus pennsylvanicus
Ondatra zibethicus
Peromyscus maniculatus
Peromyscus spp.
Reithrodontomys megalotis
Reithrodontomys montanus*
Sciurus aberti
Sciurus niger
Sciurus spp.
Spermophilus lateralis
Spermophilus tridecemlineatus
Tamias minimus
Tamias umbrinus*
Tamias spp.
Tamiasciurus hudsonicus
Thomomys talpoides
Zapus princeps

Table 5, continued.

ORDER CARNIVORA

Mephitis mephitis

Procyon lotor

BIRDS

ORDER PICIFORMES

Colpates auratus

ORDER PASSERIFORMES

Cyanocitta stelleri

Pica pica

Piranga ludoviciana

Sturnus vulgaris

Turdus migratorius

Table 6. Mammalian and avian species found in red-tailed hawk pellets or nest remains in Boulder County, Colorado. Species with a bold asterisk had never been reported previously to be consumed by red-tailed hawks.

NEST #	NAME	HAIR	BONES/TEETH	FEATHERS
1	WILD BASIN 1984			
		Marmota flaviventris		
		Tamiasciurus hudsonicus		
			*Microtus longicaudus**	
2	BVR			
		*Cynomys ludovicanus**		
		Microtus pennsylvanicus		
3	41st & OXFORD			
		*Geomys bursarius**		
		Lepus californicus		
		Peromyscus maniculatus		
		Peromyscus spp.		
		Spermophilus tridecemlineatus		
		Sylvilagus nuttallii		
			*Cynomys ludovicanus**	
				Sturnus vulgaris
4	WEISER			
		*Cynomys ludovicanus**		
		Microtus pennsylvanicus		
		Ondatra zibethicus		
		Reithrodontomys megalotis		
		Sciurus niger		
			Spermophilus tridecemlineatus	
			Sylvilagus spp.	
			*Geomys bursarius**	
			Microtus spp.	
			Microtus ochrogaster	
			Microtus pennsylvanicus	
			Ondatra zibethicus	

Table 6, continued.

			Peromyscus maniculatus	
			*Sylvilagus audubonii**	
			Sylvilagus nuttallii	
			Sylvilagus spp.	
				Piranga ludoviciana
				Sturnus vulgaris
5	103 & 72			
		*Castor canadensis**		
		Marmota flaviventris		
		Microtus pennsylvanicus		
		*Ocotona princeps**		
		Sciurus spp.		
		Sorex spp.		
		Tamias minimus		
		*Tamias umbrinus**		
		Tamias spp.		
		Tamiasciurus hudsonicus		
			Microtus spp.	
			Thomomys talpoides	
				Colaptes auratus
6	WILD BASIN 1985			
		*Castor canadensis**		
		Mephitis mephitis		
		Microtus pennsylvanicus		
		*Ochotona princeps**		
		Sciurus aberti		
			Spermophilus lateralis	
		Tamiasciurus hudsonicus		
		Zapus princeps		
			Thomomys talpoides	
				Colpates auratus
7	MATRON			
		Marmota flaviventris		
		Microtus pennsylvanicus		
		Sciurus aberti		
			Thomomys talpoides	
			*Microtus longicaudus**	

Table 6, continued.

			Sciurus spp.	
				Cyanocitta stelleri
				Pica pica
				Turdus migratorius
8	WHITE ROCKS			
		Microtus pennsylvanicus		
		Peromyscus maniculatus		
		Procyon lotor		
		*Reithrodontomys montanus**		
			*Geomys bursarius**	
			Microtus ochrogaster	
			Microtus pennsylvanicus	
			Microtus spp.	
			Ondatra zibethicans	
			Sylvilagus spp.	
				Colpatus auratus
				Sturnus vulgaris

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APPENDIX I

Published data used to calculate averages in the text. (The inspiration for this appendix and some of the categories are from Mader, 1978).

Variable	Data	Location	Source
Average territory radius (km): 1.7			
	1.9	Michigan, Wyoming	Craighead and Craighead, 1956
	2.4	Michigan	English, 1934
	0.85	California	Fitch et al., 1946
	1.8	Utah	Smith and Murphy, 1973
Approximate length of breeding season (laying -> fledging) in days: 112			
	81	Utah	Hardy, 1939
	118	Arizona	Mader, 1978
	139	Utah	Smith and Murphy, 1973
	79	Ohio	Springer and Kirkley, 1978
	141	California	Wiley, 1975
Average number of pairs laying eggs % (n): 90 (650)			
	90 (212)	Alberta	Adamcik et al., 1979
	100 (19)	Michigan, Wyoming	Craighead and Craighead, 1956
	90 (153)	Montana	Johnson, 1975
	86 (66)	Alberta	Luttich et al., 1971
	89 (107)	Alberta	McInvaile and Keith, 1974
	90 (67)	Wisconsin	Orians and Kuhlman, 1956
	81 (26)	Utah	Smith and Murphy, 1973
Average clutch size (n): 2.5 (757)			
	2.18 (191)	Alberta	Adamcik et al., 1979
	2.0 (8)	California	Fitch et al., 1946
	1.9 (33)	Kansas	Freemyer, 1966
	2.79 (476)	USA, Canada	Henny and Wight, 1972
	1.9 (30)	Alberta	Luttich et al., 1971
	2.89 (19)	Utah	Smith and Murphy, 1973
Average incubation period in days: 32			
	32	Alberta	Adamcik et al., 1979
	30	British Columbia	Beebe, 1974
	28	North America?	Bent, 1937
	35	Utah	Hardy, 1939
	35	Arizona	Mader, 1978
	30	Utah	Smith and Murphy, 1973

Average brood size (n): 2.1 (213)

2.09 (191)	Alberta	Adamcik et al, 1979
1.9 (22)	New York	Hagar, 1957

Average success from hatching to fledging % (n): 64 (123)

76 (29)	Michigan, Wyoming	Craighead and Craighead, 1956
59 (27)	California	Fitch et al., 1946
67 (12)	Utah	Platt, 1971
58.9 (55)	Utah	Smith and Murphy, 1973

Stomachs empty % (n empty/n examined): 22 (361/1630)

24 (16/68)	Iowa	Bailey, 1918
16 (89/562)	USA	Fisher, 1893
0 (0/1)	Alabama	Howell, 1924
44 (23/52)	Pennsylvania	Langenbach, 1938
0 (0/1)	Arkansas	Lano, 1926
100 (1/1)	Arkansas	Lano, 1927
34 (161 + 106 more that were "unfit" for analysis/468)	Pennsylvania	Luttringer, 1935
5 (1/20)	Maine	Mendall, 1944
27 (28/102)	Ohio	Pearson, 1933
20 (1/5)	Connecticut	Sage et al., 1913
0 (0/7)	Florida	Stoddard, 1931
38 (12/32)	Pennsylvania	Sutton, 1928
9 (29/311)	Pennsylvania	Warren, 1890

APPENDIX II

Definitions of the Habitat Suitablity Index variables for the red-tailed hawk model (USFWS, 1981: B-17). Variables V_1, V_2, and V_3 are measured for grassy cover types. Varibles V_4, and V_5 are measured for forested cover types.

V_1: Percent herbaceous canopy cover [the percent of the ground surface that is shaded by a vertical projection of all non-woody vegetation (grasses, forbs, sedges, etc.)]

V_2: Percent of herbaceous vegetation that is 8 to 46 cm (3 to 18 in) tall (self explanatory)

V_3: Number of trees $\geq$ 25 cm (10 in) dbh per 0.4 ha (1.0 ac) (self explanatory)

V_4: Percent tree canopy closure (the percent of the ground surface that is shaded by a vertical projection of the canopies of all trees)

V_5: Number of trees $\geq$ 50 cm (20 in) dbh per 0.4 ha (1.0 ac) (self explanatory)

APPENDIX III

List of all animals (scientific and common names) attributed to the diet of red-tailed hawks (*Buteo jamaicensis*).

MAMMALS

Scientific Name	Common Name	Source
ORDER INSECTIVORA		
F. Soricidae		
Blarina spp.		Errington 1933
		Errington and Breckenridge 1938
		Latham 1950
Blarina brevicauda	northern short-tailed shrew	Belyea 1976
		Craighead and Craighead 1956
		Fisher 1893
		Orians and Kuhlman 1956
		Springer and Kirkley 1978
		Sutton 1928
Blarina carolinensis	southern short-tailed shrew	Fisher 1893
		Fitch and Bare 1978
Cryptotis spp.		Latham 1950
Cryptotis parva	least shrew	Fisher 1893
		Fitch and Bare 1978
Sorex spp.		Blumstein this study
		Errington 1933
		Fisher 1893
		Latham 1950
		Schmutz et al. 1980
Sorex cinereus	masked shrew	Adamcik et al. 1979
		McInvaille and Keith 1974
F. Talpidae		
Scalopus spp.		Latham 1950
Scalopus aquaticus	eastern mole	Belyea 1976
		Fisher 1893
		Fitch and Bare 1978
		Hamerstrom and Hamerstrom 1951
		Springer and Kirkley 1978
Scapanus latimanus	broad-footed mole	Fitch et al. 1946
ORDER CHIROPTERA		
F. Vespertilionidae		
Lasiurus borealis	red bat	Fitch et al. 1946
ORDER LAGOMORPHA		
F. Ochotonidae		
Ochotona princeps	pika	Blumstein this study
F. Leporidae		
Lepus spp.		Craighead and Craighead 1956
		Lloyd 1887
Lepus americanus	snowshoe hare	Adamcik et al. 1979
		Craighead and Craighead 1956
		Luttich et al. 1970
		McInvaille and Keith 1974
		Mendall 1944
		Orians 1955
Lepus californicus	black-tailed jack rabbit	Blumstein this study
		Bryant 1918

		Fisher 1893
		Fitch et al. 1946
		Hardy 1939
		Mader 1978
		Smith and Murphy 1973
Lepus townsendii	white-tailed jack rabbit	Seidensticker 1970
Sylvilagus spp.		
		Blumstein this study
		Bohm 1978
		Cameron 1907
		Dixon 1906
		English 1934
		Errington 1933
		Fisher 1893
		Hardy 1939
		Lano 1926
		Latham 1950
		Lloyd 1887
		McDowell 1949
		Orains 1955
		Smith and Murphy 1973
Sylvilagus audubonii	desert cottontail	Blumstein this study
		Fisher 1893
		Fitch et al. 1946
		Mader 1978
		Seidensticker 1970
Sylvilagus bachmani	brush rabbit	Bond 1947
		Bryant 1918
		Sumner 1929
Sylvilagus floridanus	eastern cottontail	Belyea 1976
		Fitch and Bare 1978
		Gates 1972
		Howell et al. 1978
		Orians and Kuhlman 1956
		Petersen 1979
		Phelan and Robertson 1978
		Springer and Kirkley 1978
Sylvilagus nuttallii	Nuttall's cottontail	Blumstein this study
		Fisher 1893
		Janes 1984
		Seidensticker 1970
ORDER RODENTIA		
F. Sciuridae		
Ammospermophilus harrisii	Harris' antelope squirrel	Mader 1978
Ammospermophilus leucurus	white-tailed antelope squirrel	Smith and Murphy 1973
Cynomys spp.	prairie dogs	Knight 1902
		Lloyd 1887
Cynomys ludovicianus	black-tailed prairie dog	Blumstein this study
Glaucomys sabrinus	northern flying squirrel	Adamcik et al. 1979
		Luttich et al. 1970
		McInvaille and Keith 1974
Marmota spp.		Latham 1950
Marmota flaviventris	yellow-bellied marmot	Blumstein this study
		Craighead and Craighead 1956
Marmota monax	woodchuck	Bohm 1978

		Craighead and Craighead 1956
		Hager 1957
		McAtee 1935
		McDowell 1949
		Springer and Kirkley 1978
Sciurus spp.		Blumstein this study
		Bohm 1978
		Craighead and Craighead 1956
		Errington 1933
		Hamerstrom and Hamerstrom 1951
		Latham 1950
		Luttringer 1935
		McDowell 1949
		Pellett 1912
		Sutton 1928
Sciurus aberti	Abert's squirrel	Blumstein this study
		Fisher 1893
		Hall 1981
Sciurus arizonensis	Arizona gray squirrel	Fisher 1893
Sciurus carolinensis	gray squirrel	Fisher 1893
		Orians and Kuhlman 1956
		Phelan and Robertson 1978
Sciurus douglasii	Douglas' squirrel	Miller 1920
Sciurus griseus	western gray squirrel	Fitch et al. 1946
Sciurus niger	fox squirrel	Belyea 1976
		Blumstein this study
		Bohm 1978
		Craighead and Craighead 1956
		English 1934
		Fitch and Bare 1978
		Gates 1972
		Hamerstrom and Hamerstrom 1951
		Orians and Kuhlman 1956
		Springer and Kirkley 1978
Spermophilus spp.		Dixon 1906
		English 1934
		Houston 1975
		Knight 1902
		McAtee 1935
		Taverner 1934
Spermophilus armatus	Uinta ground squirrel	Craighead and Craighead 1956
Spermophilus beecheyi	California ground squirrel	Bond 1947
		Fitch et al. 1946
Spermophilus beldingi	Belding's ground squirrel	Janes 1984
Spermophilus columbianus	Columbian ground squirrel	Miller 1931
		Munro 1929
Spermophilus franklinii	Franklin's ground squirrel	Adamcik et al. 1979
		Criddle 1917
		Errington 1933
		Fisher 1893
		Luttich et al. 1970
		McInvaille and Keith 1974
Spermophilus lateralis	golden-mantled ground squirrel	Blumstein this study
		Fisher 1893
		Janes 1984
Spermophilus richardsonii	Richardson's ground squirrel	Adamcik et al. 1979
		Criddle 1917

		Luttich et al. 1970
		McInvaille and Keith 1974
		Schmutz et al. 1980
		Seidensticker 1970
Spermophilus tereticaudus	round-tailed ground squirrel	Mader 1978
Spermophilus townsendii	Townsend's ground squirrel	Janes 1984
		Smith and Murphy 1973
Spermophilus tridecemlineatus	thirteen-lined ground squirrel	Belyea 1976
		Blumstein this study
		Bohm 1978
		Criddle 1917
		Errington 1933
		Fisher 1893
		Gates 1972
		Hamerstrom and Hamerstrom 1951
		Luttich et al. 1970
		Orians and Kuhlman 1956
		Pellett 1912
		Springer and Kirkley 1978
Spermophilus variegatus	rock squirrel	Fisher 1893
Tamias spp.		Bennett and Rudersdorf 1980
		Blumstein this study
		Bohm 1978
		Errington 1933
		Latham 1950
		Luttringer 1935
		McDowell 1949
		Sutton 1928
Tamias merriami	Merriam's chipmunk	Fitch et al. 1946
Tamias minimus	least chipmunk	Blumstein this study
		Craighead and Craighead 1956
		Luttich et al. 1970
		Smith and Murphy 1973
Tamias striatus	eastern chipmunk	Fisher 1893
		Hamerstrom and Hamerstrom 1951
		Howell et al. 1978
		Springer and Kirkley 1978
Tamias quadrivittatus	Colorado chipmunk	Fisher 1893
Tamias umbrinus	Uinta chipmunk	Blumstein this study
Tamiasciurus hudsonicus	red squirrel	Adamcik et al. 1979
		Blumstein this study
		Bohm 1978
		Craighead and Craighead 1956
		English 1934
		Fisher 1893
		Luttich et al. 1970
		Luttringer 1935
		McDowell 1949
		McInvaille and Keith 1974
		Mendall 1944
		Seidensticker 1970
		Springer and Kirkley 1978
		Sutton 1928
		Wade 1883
		Warren 1890

F. Geomyidae		
Geomys spp.		Errington and Breckenridge 1938
Geomys bursarius	plains pocket gopher	Blumstein this study
Thomomys spp.		Fisher 1893
		Houston 1975
		Platt 1971
Thomomys bottae	Botta's pocket gopher	Bond 1947
		Bryant 1918
		Fitch et al. 1946
		Mader 1978
		Smith and Murphy 1973
		Sumner 1929
Thomomys talpoides	nothern pocket gopher	Adamcik et al. 1979
		Blumstein this study
		Craighead and Craighead 1956
		Janes 1984
		Luttich et al. 1970
		McInvaille and Keith 1974
		Munro 1929
		Seidensticker 1970
F. Heteromyidae		
Dipodomys heermanni	Heermann's kangaroo rat	Fitch et al. 1946
Dipodomys ordii	Ord's kangaroo rat	Fisher 1893
Perognathus spp.		Fitch et al. 1946
Perognathus baileyi	Bailey's pocket mouse	Mader 1978
F. Castoridae		
Castor canadensis	beaver	Blumstein this study
F. Cricetidae		
Clethrionomys spp.		Latham 1950
Clethrionomys gapperi	southern red-backed vole	Adamcik et al. 1979
		Luttich et al. 1970
		McInvaille and Keith 1974
		Sutton 1928
Microtus spp.		Bart 1977
		English 1934
		Errington 1933
		Gates 1972
		Latham 1950
		Miller 1931
		Orians and Kuhlman 1956
		Platt 1971
		Seidensticker 1970
		Smith and Murphy 1973
		Snyder 1926
		Springer and Kirkley 1978
		Warren 1890
Microtus californicus	California vole	Bond 1947
		Fitch et al. 1946
		Sumner 1929
Microtus longicaudus	long-tailed vole	Blumstein this study
Microtus montanus	montane vole	Janes 1984
Microtus ochrogaster	prairie vole	Blumstein this study
		Fitch and Bare 1978
Microtus pennsylvanicus	meadow vole	Adamcik et al. 1979
		Baker and Brooks 1981
		Belyea 1976
		Blumstein this study

		Bohm 1978
		Craighead and Craighead 1956
		Dixon 1906
		Fisher 1893
		Hamerstrom and Hamerstrom 1951
		Luttich et al. 1970
		McAtee 1935
		McInvaille and Keith 1974
		Mendall 1944
		Munro 1929
		Phelan and Robertson 1978
		Sutton 1928
Microtus pinetorum	woodland vole	Fisher 1893
		Hamerstrom and Hamerstrom 1951
Neotoma spp.	woodrats	McAtee 1935
Neotoma albigula	white-throated woodrat	Mader 1978
Neotoma cinerea	bushy-tailed woodrat	Craighead and Craighead 1956
Neotoma floridana	eastern woodrat	Fitch and Bare 1978
Neotoma fuscipes	dusky-footed woodrat	Fitch et al. 1946
Neotoma mexicana	Mexican woodrat	Fisher 1893
Ondatra zibethicus	muskrat	Adamcik et al. 1979
		Belyea 1976
		Blumstein this study
		Craighead and Craighead 1956
		Fitch and Bare 1978
		Gates 1972
		Luttich et al. 1970
		McAtee 1935
		McInvaille and Keith 1974
		Petersen 1979
		Phelan and Robertson 1978
		Seidensticker 1970
Onychomys torridus	southern grasshopper mouse	Mader 1978
Peromyscus spp.		Blumstein this study
		Craighead and Craighead 1956
		Errington 1933
		Springer and Kirkley 1978
Peromyscus boylii	brush mouse	Fitch et al. 1946
Peromyscus leucopus	white-footed mouse	Fitch and Bare 1978
Peromyscus maniculatus	deer mouse	Adamcik et al. 1979
		Blumstein this study
		Fisher 1893
		Fitch and Bare 1978
		Janes 1984
		Luttich et al. 1970
		McInvaille and Keith 1974
		Seidensticker 1970
		Smith and Murphy 1973
		Sumner 1929
Peromyscus truei	piñon mouse	Fitch et al. 1946
Reithrodontomys spp.		Errington and Breckenridge 1938
Reithrodontomys humilis	eastern harvest mouse	Fisher 1893
Reithrodontomys megalotis	western harvest mouse	Blumstein this study
		Fitch and Bare 1978
		Fitch et al. 1946
Reithrodontomys montanus	plains harvest mouse	Blumstein this study

Sigmodon spp.	cotton rats	McAtee 1935
Sigmodon hispidus	hispid cotton rat	Fisher 1893 Fitch and Bare 1978
Synaptomys cooperi	southern bog lemming	Fisher 1893
F. Muridae		
Mus musculus	house mouse	Errington 1933 Errington and Breckenridge 1938 Fisher 1893 Fitch and Bare 1978 McAtee 1935
Rattus norvegicus	Norway rat	Bond 1947 Craighead and Craighead 1956 Errington 1933 Fisher 1893 Gates 1972 Lantz 1909 Luttringer 1935 Petersen 1979 Springer and Kirkley 1978 Sutton 1928
Rattus rattus	black rat	McAtee 1935
F. Zapodidae		
Zapus hudsonius	meadow jumping mouse	Adamcik et al. 1979 Belyea 1976 Bohm 1978 Fisher 1893 Fitch and Bare 1978 Luttich et al. 1970 McInvaille and Keith 1974 Orians and Kuhlman 1956
Zapus princeps	western jumping mouse	Blumstein this study Seidensticker 1970
F. Erethizontidae		
Erethizon dorsatum	porcupine	Fisher 1883 McAtee 1935
ORDER CARNIVORA		
F. Canidae		
Canis latrans	coyote	Fitch et al. 1946
Vulpes vulpes	red fox	McDowell 1949
F. Procyonidae		
Procyon lotor	raccoon	Blumstein this study Craighead and Craighead 1956 Luttringer 1935 McDowell 1949
F. Mustelidae		
Mephitis mephitis	striped skunk	Adamcik et al. 1979 Blumstein this study Fisher 1893 Luttich et al. 1970
Mustela spp.		Craighead and Craighead 1956 English 1934 Errington 1933
Mustela erminea	ermine	Adamcik et al. 1979 Luttich et al. 1970 McInvaille and Keith 1974
Mustela frenata	long-tailed weasel	Hamerstrom and Hamerstrom 1951 Luttich et al. 1970

		McInvaille and Keith 1974
Mustela nivalis	least weasel	Adamcik et al 1979
		Luttich et al. 1970
		McInvaille and Keith 1974
Mustela vison	black-footed ferret	Errington and Breckenridge 1938
F. Felidae		
Felis rufus	bobcat	Fitch et al. 1946
ORDER PERRISODACTYLA		
F. Equidae		
Equus caballus	horse	Fitch et al 1946
ORDER ARTIODACTYLA		
F. Suidae		
Sus spp.	pigs	Errington and Breckenridge 1938
		Orians and Kuhlman 1956
		Warren 1890
F. Bovidae		
Bos taurus	cow	Fitch et al. 1946
Ovis aries	sheep	Barney 1959
		Fitch et al. 1946

BIRDS

ORDER PODICIPEDIFORMES		
Podiceps grisengena	red-necked grebe	Adamcik et al. 1979
		McInvaille and Keith 1974
ORDER CICONIIFORMES		
Butorides virescenis	green heron	Belyea 1976
Nycticorax nycticorax	black-crowned night heron	Bailey 1918
ORDER ANSERIFORMES		
Anas spp.	ducks	Seidensticker 1970
Anas acuta	northern pintail	Adamcik et al. 1979
		McInvaille and Keith 1974
		Fisher 1893
Anas americana	American widgeon	Adamcik et al. 1979
		McInvaille and Keith 1974
Anas carolinensis	green-winged teal	Adamcik et al. 1979
		McInvaille and Keith 1974
Anas clypeata	northern shoveler	Adamcik et al. 1979
		McInvaille and Keith 1974
Anas discors	blue-winged teal	Adamcik et al. 1979
		McInvaille and Keith 1974
Anas platyrhynchos	mallard	Adamcik et al. 1979
		Bohm 1978
		McInvaille and Keith 1974
Anas strepera	gadwall	Adamcik et al. 1979
		McInvaille and Keith 1974
Aythya affinis	lesser scaup	Adamcik et al. 1979
		McInvaille and Keith 1974
Aythya americana	redhead	Adamcik et al. 1979
		McInvaille and Keith 1974
Aythya collaris	ring-necked duck	Adamcik et al. 1979
		McInvaille and Keith 1974
Bucephala albeola	bufflehead	Adamcik et al. 1979
		McInvaille and Keith 1974

ORDER FALCONIFORMES

Accipter cooperi	Cooper's hawk	Adamcik et al. 1979
		Luttich et al. 1970
		McInvaille and Keith 1974
		Peyton 1945
Buteo jamaicensis	red-tailed hawk	Coffin 1906
Buteo lineatus	red-shouldered hawk	Burtch 1927
Circus cyaneus	northern harrier	Luttich et al. 1970
Falco peregrinus	peregrine falcon	Beebe 1960
Falco sparverius	American kestrel	Adamcik et al. 1979
		Luttich et al. 1970
		McInvaille and Keith 1974

ORDER GALLIFORMES

Alectoris graeca	rock partridge	Janes 1984
Bonasa umbellus	ruffed grouse	Adamcik et al. 1979
		Bohm 1978
		Fisher 1893
		Luttich et al. 1970
		McAtee 1935
		McDowell 1949
		McInvaille and Keith 1974
		Seidensticker 1970
Callipepla californicus	quail	Fitch et al. 1946
Callipepla gambelii	Gambel's quail	Fisher 1893
Callipepla squamata	scaled quail	Lloyd 1887
		McAtee 1935
Centrocercus urophasianus	sage grouse	Craighead and Craighead 1956
		Seidensticker 1970
Colinus spp.	bobwhite	McAtee 1935
Colinus virginanus	northern bobwhite	Errington and Breckenridge 1938
		Fisher 1893
		Springer and Kirkley 1978
Gallus spp.	domestic chicken	Adamcik et al. 1979
		Bailey 1918
		Errington 1933
		Gates 1972
		Lano 1927
		Latham 1950
		Luttich et al. 1970
		Luttringer 1935
		McAtee 1935
		McInvaille and Keith 1974
		Mendall 1944
		Orians and Kuhlman 1956
		Pellett 1912
		Petersen 1979
		Seidensticker 1970
		Sutton 1928
		Wade 1883
		Warren 1890
		Wood 1869
Perdix perdix	gray partridge	Adamcik et al. 1979
		Beebe 1974
		English 1934
		Errington and Breckenridge 1938

		Gates 1972
		Luttich et al. 1970
		McAtee 1935
		McInvaille and Keith 1974
		Seidensticker 1970
Phasianus colchicus	ring-necked pheasant	Belyea 1976
		Errington and Breckenridge 1938
		Gates 1972
		Latham 1950
		McDowell 1949
		Orians and Kuhlman 1956
		Petersen 1979
		Springer and Kirkley 1978
Tympanuchus spp.	prairie chicken	McAtee 1935
Tympanuchus phasianellus	sharp-tailed grouse	Adamcik et al. 1979
		Luttich et al. 1970
		McAtee 1935
		McInvaille and Keith 1974
ORDER GRUIFORMES		
Fulica americana	American coot	Adamcik et al. 1979
		Bohm 1978
		Hubbard 1947
		Luttich et al. 1970
		McInvaille and Keith 1974
		Page and Whitacre 1975
Gallinula chloropus	common moorhen	Errington 1933
Porzana carolina	sora	Adamcik et al. 1979
		Hamerstrom and Hamerstrom 1951
Rallus elegans	king rail	Fisher 1893
Rallus limicola	Virgina rail	Bohm 1978
ORDER CHARADRIIFORMES		
Catoptrophorus semipalmatus	willet	Page and Whitacre 1975
Charadrius vociferus	killdeer	Adamcik et al. 1979
		McInvaille and Keith 1974
Larus pipixcan	Franklin's gull	Luttich et al. 1970
Phalaropus tricolor	Wilson's phalarope	Seidensticker 1970
ORDER COLUMBIFORMES		
Columba fasciata	band-tailed pigeon	Beebe 1974
Columba livia	rock dove	Adamcik et al. 1979
		McInvaille and Keith 1974
		Orians and Kuhlman 1956
		Springer and Kirkley 1978
Zenaida macroura	mourning dove	Errington and Breckenridge 1938
		Fisher 1893
		Gates 1972
		Springer and Kirkley 1978
ORDER CUCULIFORMES		
Geococcyx californianus	greater roadrunner	Fitch et al. 1946
ORDER STRIGIFORMES		
Asio flammeus	short-eared owl	Craighead and Craighead 1956
Otus spp.	screech owl	Finley 1905

Otus asio	eastern screech owl	McAtee 1935 Fisher 1893 Fitch et al. 1946
ORDER CAPRIMULGIFORMES		
Chordeiles minor	common nighthawk	Luttich et al. 1970
ORDER CORACIIFORMES		
Ceryle alcyon	belted kingfisher	Snyder 1926
ORDER PICIFORMES		
Asyndesmus lewis	Lewis' woodpecker	Fitch et al. 1946
Colaptes spp.	flickers	English 1934 Hamerstrom and Hamerstrom 1951
Colaptes auratus	northern flicker	Adamcik et al. 1979 Blumstein this study Gates 1972 Luttich et al. 1970 McInvaille and Keith 1974 Orians and Kuhlman 1956
Colaptes cafer	red-shafted flicker	Craighead and Craighead 1956 Fitch et al. 1946 Seidensticker 1970
Melanerpes erythrocephalus	red-headed woodpecker	Fisher 1893
Melanerpes formicivorus	acorn woodpecker	Fitch et al. 1946
Picoides villosus	hairy woodpecker	Adamcik et al. 1979 Belyea 1976 McInvaille and Keith 1974
Sphyrapicus varius	yellow-bellied sapsucker	Adamcik et al. 1979 Luttich et al. 1970 McInvaille and Keith 1974
ORDER PASSERIFORMES		
Agelaius phoeniceus	red-winged blackbird	Belyea 1976 Bohm 1978 Gates 1972 Hamerstrom and Hamerstrom 1951 Luttich et al. 1970 Orians and Kuhlman 1978 Springer and Kirkley 1978
Ammodramus savannarum	grasshopper sparrow	Fisher 1893
Aphelocoma coerulescens	scrub jay	Fitch et al. 1946
Cardinalis cardinalis	northern cardinal	Springer and Kirkley 1978
Carduelis tristis	American goldfinch	Luttich et al. 1970 Springer and Kirkley 1978
Carpodacus mexicanus	house finch	Bond 1947 Fitch et al. 1946
Catharus guttatus	hermit thrush	Sutton 1928
Chondestes grammacus	lark sparrow	Fitch et al. 1946
Corvus spp.	crows	Bailey 1918 Bohm 1978 Criddle 1917 McAtee 1935 McDowell 1949
Corvus brachyrhynchos	American crow	Baumgrass 1945 Belyea 1976 Craighead and Craighead

		1956
		Fisher 1893
		Gates 1972
		Hogan 1983
		Luttich et al. 1970
		Orians and Kuhlman 1956
		Seidensticker 1970
		Stinson 1980
Cyanocitta cristata	blue jay	Gates 1972
		Hamerstrom and Hamerstrom 1951
		Luttich et al. 1970
Cyanocitta stelleri	Steller's jay	Blumstein this study
Dendroica spp.	warbler	Luttich et al. 1970
Dendroica petechia	yellow warbler	Adamcik et al. 1979
		McInvaille and Keith 1974
Dumetella carolinensis	gray catbird	Gates 1972
Eremophila alpestris	horned lark	Janes 1984
		Smith and Murphy 1973
Euphagus cyanocephalus	Brewer's black-bird	Craighead and Craighead 1956
		Luttich et al. 1970
		Seidensticker 1970
Icterus spurius	orchard oriole	Fisher 1893
Junco hyemalis	dark-eyed junco	Fisher 1893
Melospiza melodia	song sparrow	Errington and Breckenridge 1938
		Fisher 1893
		Springer and Kirkley 1978
		Sutton 1928
Molothrus spp.	cowbirds	Luttich et al. 1970
Molothrus ater	brown-headed cowbird	Orians and Kuhlman 1956
Passer domesticus	house sparrow	Gates 1972
Perisoreus canadensis	gray jay	Adamcik et al. 1979
		Luttich et al. 1970
		McInvaille and Keith 1974
Pheucticus ludovicianus	rose-breasted grosbeak	Luttich et al. 1970
Pica pica	black-billed magpie	Adamcik et al. 1979
		Blumstein this study
		Janes 1984
		Luttich et al. 1970
		McInvaille and Keith 1974
		Seidensticker 1970
Pipilo erythrophthalmus	rufous-sided towhee	Bond 1947
		Fitch et al. 1946
Pipilo fuscus	brown towhee	Fitch et al. 1946
Piranga ludoviciana	western tanager	Blumstein this study
		Seidensticker 1970
Poocoetus gramineus	vesper sparrow	Criddle 1917
		Fisher 1893
Quiscalus quiscula	common grackle	Fisher 1893
		Gates 1972
		Springer and Kirkley 1978
Seiurus aurocapillus	ovenbird	Luttich et al. 1970
Sialia currucoides	mountain bluebird	Janes 1984
		Smith and Murphy 1973
Sialia mexicana	western bluebird	Fitch et al. 1946
Sialia sialis	eastern bluebird	Fisher 1893
Spizella arborea	American tree sparrow	Fisher 1893

Sturnella spp.		Cameron 1907
		McAtee 1935
		Orains and Kuhlman 1956
		Warren 1890
Sturnella magna	eastern meadowlark	Fisher 1893
Sturnella neglecta	western meadowlark	Fitch et al. 1946
		Janes 1984
		Seidensticker 1970
Sturnus vulgaris	European starling	Adamcik et al. 1979
		Belyea 1976
		Blumstein this study
		English 1934
		Luttich et al. 1970
		McInvaille and Keith 1974
		Orians and Kuhlman 1956
		Seidensticker 1970
		Smith and Murphy 1973
		Springer and Kirkley 1978
Troglodytes troglodytes	winter wren	Sutton 1928
Tyrannus tyrannus	eastern kingbird	Seidensticker 1970
Tyrannus verticalis	western kingbird	Fitch et al. 1946
		Smith and Murphy 1973
Turdus spp.	robins	McAtee 1935
Turdus migratorius	American robin	Adamcik et al. 1979
		Blumstein this study
		Craighead and Craighead 1956
		Fisher 1893
		Luttich et al. 1970
		McInvaille and Keith 1974
		Seidensticker 1970
Zonotrichia spp.		Fitch et al. 1946

AMPHIBIANS AND REPTILES

ORDER CAUDATA		Latham 1950
		McAtee 1935
		McDowell 1949
Ambystoma spp.	mole salamanders	Errington and Breckenridge 1938
ORDER SALIENTIA		Blumstein this study
		Errington 1933
		Latham 1950
		McAtee 1935
		McDowell 1949
		Mendall 1944
		Wade 1883
Bufo spp.	toads	Errington and Breckenridge 1938
		Fitch and Bare 1978
Bufo americanus	American toad	Belyea 1976
		Hamerstrom and Hamerstrom 1951
Bufo cognatus	great plains toad	Luttich et al. 1970
Rana spp.		Luttich et al. 1970
		Orians and Kuhlman 1956
		Springer and Kirkley 1978
Rana clamitans	green frog	Errington and Breckenridge

		1938
ORDER TESTUDINES		McAtee 1935
ORDER SAURIA		McAtee 1935
		Platt 1971
Cnemidophorus sexlineatus	six-lined racerunner	Fitch and Bare 1978
Cnemidophorus tesselatus	Colorado checkered whiptail	Fitch et al. 1946
Crotaphytus collaris	collared lizard	Smith and Murphy 1973
Eumeces gilberti	Gilbert's skink	Fitch et al. 1946
		Fitch and Bare 1978
Gerrhonotus coeruleus	northern alligator lizard	Bond 1947
Gerrhonotus multicarinatus	southern alligator lizard	Fitch et al. 1946
Ophisaurus attenuatus	slender glass lizard	Fitch and Bare 1978
Phrynosoma spp.	horned lizards	Mader 1978
Sceloporus magister	desert spiny lizard	Mader 1978
Sceloporus occidentalis	western fence lizard	Fitch et al. 1946
Uta stansburiana	side-blotched lizard	Fitch et al. 1946
ORDER SERPENTES		Luttringer 1935
		McDowell 1949
		Warren 1890
		Wood 1869
Agkistrodon contortrix	copperhead	Fitch and Bare 1978
Coluber constrictor	racer	Fitch and Bare 1978
		Hamerstrom and Hamerstrom 1951
		Janes 1984
		McAtee 1935
		Stinson 1980
Crotalus spp.	rattlesnakes	Cameron 1907
		Jensen 1926
		Mader 1978
Crotalus horridus	timber rattlesnake	Fitch and Bare 1978
Crotalus molossus	blacktail rattlesnake	Johnson 1964
Crotalus viridis	western rattlesnake	Fitch et al. 1946
Diadophis punctatus	ringneck snake	Fitch and Bare 1978
Elaphe obsoleta	rat snake	Fitch and Bare 1978
Heterodon spp.	hognose snake	Errington and Breckenridge 1938
		McAtee 1935
Lampropeltis spp.		Fitch and Bare 1978
Lampropeltis getulus	common kingsnake	Fitch et al. 1946
Lampropeltis triangulum	milk snake	English 1934
Masticophis lateralis	striped racer	Dixon 1906
Masticophis taeniatus	striated whipsnake	Smith and Murphy 1973
Nerodia sipedon	northern water snake	Fitch and Bare 1978
Pituophis spp.		Dixon 1906
		Errington 1933
		Errington and Breckenridge 1938
		Jensen 1926
		McAtee 1935
Pituophis catenifer	pacific gopher snake	Bond 1947
		Fitch et al. 1946

		Hardy 1939
Pituophis melanoleucus	gopher snake	Fitch and Bare 1978
		Janes 1984
		Mader 1978
		Stinson 1980
		Smith and Murphy 1973
Rhinocheilus lecontei	hognose snake	Fitch et al. 1946
Thamnophis spp.		Craighead and Craighead 1956
		Errington 1933
		Errington and Breckenridge 1938
		Fitch et al. 1946
		Latham 1950
		McAtee 1935
		Mendall 1944
		Seidensticker 1970
		Springer and Kirkley 1978
Thamnophis sirtalis	common garter snake	Belyea 1976
		Fitch and Bare 1978
		Sutton 1928

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ORDER SALMONIFORMES		
Oncorhynchus keta	chum salmon	Stalmaster 1980
ORDER CYPRINIFORMES		Finley 1905
Catostomus spp.	suckers	Seidensticker 1970
Cyprinus carpio	common carp	Seidensticker 1970
ORDER SILURIFORMES		Finley 1905

INVERTEBRATES

CLASS ARACHNIDA		
O. Araneae	spiders	McAtee 1935
		Pearson 1933
F. Arachnids		Fitch et al. 1946
O. Scorpionidae	scorpions	Fitch et al. 1946
CLASS CHILOPODA		
O. Chilopoda	centipedes	Fitch et al. 1946
		McAtee 1935
CLASS CRUSTACEA		
F. Astacidae	crayfish	Fitch and Bare 1978
		Gates 1972
		McAtee 1935
		McDowell 1949
		Pearson 1933
CLASS INSECTA		Bailey 1918
		Fitch and Bare 1978
		Latham 1950
		Luttringer 1935
		McDowell 1949
		Mendall 1944
		Pearson 1933
		Warren 1890

O. Coleoptera	beetles	Fitch and Bare 1978 Gates 1972 Luttringer 1935
F. Buprestidae		
Acmaeodera spp.		Fitch et al. 1946
Buprestid spp.		Fitch et al. 1946
Polycesta spp.		Fitch et al. 1946
F. Byrrhidae		
Amphicyrta spp.		Fitch et al. 1946
F. Carabidae		
Amara spp.		Fitch et al. 1946
Calosoma spp.		Errington and Breckenridge 1938
Carabid spp.		Fitch et al. 1946
F. Chrysomelidae		
Leptinotarsa decemlineata	Colorado potato beetle	McAtee 1908
Odonata spp.		Fitch et al. 1946
F. Elateridae		
Elaterid spp.		Fitch et al. 1946 Sutton 1928
F. Hydrophilinae		
Hydrous spp.		Fitch et al. 1946
F. Scarabaeidae		
Phobetus comatus		Fitch et al. 1946
Scarabeid spp.		Fitch et al. 1946
Serica spp.		Fitch et al. 1946
Silpha spp.		Fitch et al. 1946
F. Tenebrionidae		
Coniontis spp.		Fitch et al. 1946
Eleodes spp.		Fitch et al. 1946
Nyctoporis spp.		Fitch et al. 1946
Tenebrionid spp.		Fitch et al. 1946
O. Diptera	flies	
F. Californidae		
Lucilia spp.		Fitch et al. 1946
F. Cuterebridae		
Cuterebra spp.		Fitch et al. 1946
O. Hemiptera		
F. Belostomatidae		
Belostomatid spp.		Fitch et al. 1946
F. Corixidae		
Corixid spp.		Fitch et al. 1946
O. Homoptera		
F. Diaspididae		
O. Hymenoptera		
F. Formicidae	ants	Fitch et al. 1946
F. Vespidae		
Vespula spp.	hornets	Fitch et al. 1946
O. Lepodoptera	moths and butterflies	Fitch et al. 1946 McAtee 1935
O. Orthoptera	crickets and grasshoppers	Sutton 1928
F. Acrididae		Fitch et al. 1946 Howell 1924

		Luttringer 1935 McAtee 1935 Mendall 1944 Sutton 1928
Melanoplus spp.	grasshoppers	Errington and Breckenridge 1938
F. Decticidae	crickets	
Anabrus longipes		Munro 1929
F. Gryllidae		
Gryllus spp.	field crickets	Errington and Breckenridge 1938
F. Stenopelmatidae		
Stenopelmatus fuscus	Jerusalem cricket	Fitch et al. 1946
CLASS NEMATODA		Luttringer 1935