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Conservation Assessment for the American Kestrel in the Black Hills National Forest, South Dakota and Wyoming

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INTRODUCTION

This report assesses the biology and conservation status of the American kestrel (*Falco sparverius*) in the Black Hills National Forest of South Dakota and Wyoming. The goal of this assessment is to assimilate historical and current literature on the kestrel to provide managers and the general public an objective overview of this species' status within the Black Hills. Peer-reviewed scientific literature was the primary information source used in this report, however unpublished federal and state government reports provided additional valuable insight.

Little has been published on the kestrel in the Black Hills region of South Dakota and Wyoming. Therefore extrapolation of information across geographic lines was necessary. This extrapolation assumed that behavior and biology of these falcons was similar across geographic regions. Efforts were made to use literature that was based on geographic areas as close to South Dakota and Wyoming as possible.

Areas Of Uncertainty

Extrapolation of information regarding species across geographic lines can be cause for concern. No region in North America is an exact match in forest composition, elevation, etc., so kestrel ecology in the Black Hills may be different from kestrel ecology other parts of their range.

CURRENT MANAGEMENT SITUATION

Management Status/Existing Management Plans

The American kestrel is common throughout North America. Within the United States, neither the U.S. Fish and Wildlife Service nor the U.S. Forest Service list the kestrel as having special conservation status.

The kestrel is listed as "common and widespread" in the South Dakota Breeding Bird Atlas (SDBBA) (Peterson 1995). The SDBBA also lists the kestrel as a woodland–grassland (edge) species with a significant positive Breeding Bird Survey (BBS) trend in South Dakota. Similarly, the South Dakota Ornithologists' Union (SDOU) refers to the kestrel as a "fairly common summer resident" and does not apply special management status to the species (SDOU 1991). Concurrently, within Wyoming and Montana the kestrel has no special management status, and breeds across the states, especially at elevations below 2600 m (Bergeron et al. 1992, Luce et al. 1997).

REVIEW OF TECHNICAL KNOWLEDGE

Systematics/Taxonomy

The American kestrel is the smallest and most common North American falcon. Lengths range between 23 – 31 cm. Wingspans reach 51 – 62 cm, and weights average 110 gm (Balgooyen 1976, Terres 1980. Farrand 1988). Females are on average 8 % larger than males (Dunning

1984).

Adults of both sexes have a rufous red back and tail. Males have blue-gray wings, while the females have brown wings. On the tail males have a black subterminal band and females have dark barring. Kestrels show a black and white facial pattern with dark bands extending vertically down the sides of the face, as is typical of falcons. The raptor species most similar in size is the sharp-shinned hawk (*Accipiter striatus*), but that species is distinguished by short rounded wings, compared to long tapered wings of the kestrel (Terres 1980, Farrand 1988). Juvenile kestrels resemble adults but with heavier, darker streaking overall.

Distribution And Abundance

Overall Range

The American kestrel is widespread across both the North and South American continents. A eurytopic species, the kestrel ranges from the tree line in Alaska (~ 65° latitude) to Tierra del Fuego at the southern tip of South America. Suitable habitats within this range consist of forest/grassland or shrubland ecotones. These edge habitats are exploited for nesting and hunting (Balgooyen 1976). There are probably not elevation limits on the range of kestrels. In Colorado a nest with young was reported at 2800 m (Kingery 1998). Within the BHNF elevation probably will not limit kestrels.

Local Distribution And Abundance

The kestrel is listed as "common and widespread" by the South Dakota Breeding Bird Atlas (SDBBA) (Peterson 1995). The SDBBA also lists the kestrel as a woodland–grassland (edge) species with a significant, positive BBS trend in South Dakota. Similarly, the South Dakota Ornithologist's Union (SDOU) refers to the kestrel as a "fairly common summer resident" and does not apply special management status to the species (SDOU 1991). Kestrels were observed in 55.6% of 69 random blocks, 40.2% of all blocks, and in 94.0% of the regions sampled in South Dakota (Peterson 1995). Wyoming considers the kestrel a common and widespread species (Luce et al. 1997).

Within the BHNF kestrels are present but probably not in great abundance. The BBS suggests that there are probably less than 0.1 kestrels per route surveyed (a route consists of a 24.5 mile section of road surveyed each 0.5) (Sauer et al. 2000). South Dakota and the BHNF fall entirely within the range of the kestrel. Low abundance may indicate sub-optimal habitat or incomplete sampling.

Population Trend

The BBS was used to investigate kestrel population trends. The results are open to interpretation. The western region showed a 1.08% decline in population per year from 1980 – 2000 ($P = 0.04$). Fish and Wildlife Service (FWS) Region 6, which includes the BHNF, also showed a decline of 1.83% per year over the same time period ($P = 0.05$).

Trend analysis for the Black Hills region is inconclusive. Numbers reported by the BBS suggest a 24.6 % decline in population per year from 1966 – 1999 ($P = 0.20$), a 3.3% increase per year from 1966 – 2000 ($P = 0.91$) and a 9.3% decline per year from 1980 – 2000 ($P = 0.67$). These numbers are uninterpretable for several reasons. First, the tests are insignificant even at a liberal alpha level of 0.10. Also, although 95 % confidence intervals are given for the trends, they all overlap zero, suggesting no trend was observed. Finally the BBS website refers to the Black Hills as having poor "regional credibility". The BBS states: " This category reflects data with an important deficiency. In particular: the regional abundance is less than 0.1 birds/route (very low abundance), the sample is based on less than 5 routes for the long term, or is based on less than 3 routes for either subinterval (very small samples), or the results are so imprecise that a 5 % /year change would not be detected over the long term (very imprecise)" (Sauer et al. 2000).

Therefore, data for the Black Hills are inconclusive due to inadequate sample sizes and lack of statistical power to accurately interpret the population trend. It is possible to speculate that because the Western Region of the BBS and the FWS Region 6 have seen a 1.08 – 1.83 % decrease per year from 1980 – 2000, the BHNF may be seeing a similar trend. The Western Region and FWS Region 6 data have adequate sample sizes for accurate interpretation of the statistical results.

The Christmas Bird Count (CBC) (Sauer et al. 1996) is probably not reliable for estimating population trends for the kestrel in the Black Hills, because kestrels are considered a summer resident and generally migrate out of South Dakota and Wyoming in the winter when the survey takes place.

Broad Scale Movement Patterns

Kestrel movement patterns are not well documented. It is known that birds in the northern part of the range migrate, while more southern populations are less migratory or resident. Information from band recoveries suggests that birds living furthest north migrate furthest south (Varland et al. 1992). Males typically winter slightly further north and arrive on breeding grounds earlier than females (Arnold 1991).

Migration counts at Hawk Ridge, MN reported that numbers of migrating kestrels increased between 1973 and 1995. Only 550 kestrels migrated through Hawk Ridge in 1973. The numbers peaked in 1994 with 2700 individuals counted and then dropped to about 1550 in 1995. The peak of fall migration is between August 15 – October 10 (www.hawkridge.org 2000). Migration routes of kestrels between the Black Hills and their winter grounds are unknown. We might theorize however, that kestrels nesting in the BHNF may winter in the south central United States or further south into northern Mexico.

Habitat Characteristics

Nesting Habitat

Kestrels are secondary cavity nesters, primarily using abandoned woodpecker holes. Northern flickers (Colaptes *auratus*) provide preferred nest holes, however kestrels also use holes excavated by a variety of other woodpecker species (Stys 1993, Balgooyen 1976). In addition to woodpecker holes, kestrels are able to exploit other nesting opportunities. Black-billed magpie (*Pica hudsonica*) nests are used, as well as cavities in cliffs, buildings and cacti (Hamerstrom et al. 1973, Balgooyen 1976, Craig and Trost 1979, Becker 1987).

Balgooyen (1976) described several parameters of kestrel nests in the Sierra Nevada Mountains in California. Kestrels used nests an average of 7.78 m high, in a tree with a diameter at breast height (dbh) of 73.2 cm. Nest holes averaged 69.2 mm high and 67.3 mm wide and faced east significantly more than expected. Nest trees tended to be in valleys or draws more than on ridges and on level or gently sloping east facing slopes.

In areas where trees and snags are not available for nest sites, kestrels readily occupy nest boxes (Hamerstrom et al. 1973, Stys 1993, Rohrbaugh and Yahner 1997). In Pennsylvania kestrels most frequently used boxes with high nestling light intensity (amount of light penetrating the box), and boxes unobstructed by foliage. Occupied nest boxes were associated with extremely open habitat father from forest than unused boxes. Boxes that faced southeast were used more frequently than expected (Rohrbaugh and Yahner 1997).

Foraging Habitat

Kestrels inhabit a variety of open or partly open habitats across their range. Considered an edge species, kestrels rely on forest/grassland or shrubland ecotones for their hunting and nesting requirements (Balgooyen 1976, Terres 1980).

In Kentucky, wintering kestrels hunted in pastureland 76.9%, old field 18.4%, cropland 4.2%, plowed field 1.4%, and woodlots 0.8% of the time (Sferra 1984). Woodlot use may have been an artifact of perch sites used by kestrels scanning open territory.

Though not common in Quebec, Canada, one study showed that kestrels there utilized farmland habitats. Old fields are used in greater proportion than all other habitats surveyed (Jobin et al. 1998).

Toland (1987) found that in Missouri kestrels foraged more than expected (61%) in disturbed grasslands. Croplands and woodlots were underutilized (3.5 and 4.0%). Use of old fields, undisturbed grasslands and plowed fields was in proportion to availability. These results are not representative of kestrels in all regions however.

In general kestrels forage in open habitats. Unlike Toland's (1987) study, other studies across their range suggest that kestrels will forage in a variety of grassland and cropland habitats. Heavy cover is generally avoided, and woodlots are used for nest and perch sites. Also kestrels commonly perch above roadways on electric lines and poles, in areas affording open habitat. Forest roads may not fulfill this need and thus kestrels may only occupy roadways through range and grassland in the BHNF. There have been no studies on kestrels in the BHNF that we are aware of. However, general habitat use should be consistent with studies throughout their range. Pastureland and grassland will likely be the main component of kestrel foraging habitat in the BHNF. Meadows and edge habitat are common in the BHNF therefore these areas should be searched for kestrels.

Food Habits

Kestrels are opportunistic feeders, taking mammalian, avian, reptilian and invertebrate prey species. Though probably a minor component of the diet, carrion has also been reported as a food source for kestrels (Ganis 1976). Throughout their range, diets differ with what prey items are most available in each area. Balgooyen (1976) found that kestrels in California switched prey items as the breeding season progressed. Early in the season, kestrels captured mostly birds and small mammals; later, lizards and insects, and finally insects dominated their diets from midseason until dispersal.

In Idaho, avian prey made up the majority of biomass in kestrel diets (67.8%). Small mammals, reptiles and insects made up 15.7%, 15.8% and 0.7% of the diet respectively (Craig and Trost 1979).

Highlighting the importance of mammalian, avian and invertebrate prey, Johnsgard (1990) summarized a diet review by Sherrod (1978). Of 10 studies reviewed, the majority (6) proposed kestrel diet was comprised of 1 – 54% mammalian prey, 0 – 20.5% avian prey, and 32 – 99% insects.

Though no studies specific to kestrels in the Black Hills region were available, diet composition can be surmised. Within the BHNF small mammals and birds will undoubtedly make up the majority of prey items taken and biomass of kestrel diet. Examples might include deer mice, vole spp, horned larks, and sparrow spp. Reptiles, such as grass snakes, and insects, such as grasshoppers, may be secondary to the diet overall but important at certain times of the season. Insects may be especially important during outbreaks or times of increases in populations, i.e.: grasshoppers.

Breeding Biology

Pair bonding in kestrels is strong and may be permanent (Johnsgard 1990). Photoperiod appears to be an important factor in determining timing of courtship and egg laying (Willoughby and Cade 1964).

Courtship Characteristics

Johnsgard (1990) summarized courtship characteristics for kestrels. There appears to be a pattern of philopatry in kestrels. Reinforcement of pairs begins when the kestrels return to a breeding territory. Males generally arrive first and females follow (Arnold 1991). Aerial displays, nest searches and feeding by the male reinforce pair bonds. Bonding is complete when a female associates with a single male on his territory (Johnsgard 1990).

Nest Characteristics

Kestrels are secondary cavity nesters. Abandoned woodpecker holes are their primary natural nest sites. Northern flickers provide preferred nest holes, however kestrels also use holes excavated by a variety of woodpecker species (Stys 1993, Balgooyen 1976). In addition, kestrels are able to exploit other nesting opportunities. Magpie nests have been reportedly used as nests, as well as cavities in cliffs, buildings and cacti (Hamerstrom et al. 1973, Craig and Trost 1979, Becker 1987, Balgooyen 1976).

Balgooyen (1976) described several parameters of kestrel nests in California. Kestrels preferred their nests to be an average of 7.78 m high, in a tree with a dbh of 73.2 cm. Nest holes averaged 69.2 mm high and 67.3 mm wide. Nests faced east significantly more than would be expected. Nest trees tended to be in valleys or draws more than on ridges, and on level or gently sloping east facing slopes.

Stys (1993) reviewed kestrel ecology in Florida. Most tree nest cavities were located in snags (96.7%). These snags were in an intermediate stage of decay (twigs absent, a few main limbs >

1 m in length, < 50% of the top of the tree intact, and approximately 33% of the bark intact). The dbh for nest snags averaged 30.45 cm and the nest hole was 7.25 m above the ground. The mean hole width was 72.25 mm with a height of 94.25 mm. The majority of nest sites in Florida were in association with pastures or cultivated farmland.

In Idaho the average nest entrance diameter was reported as 93 mm ± 35mm. The average nest height was 2.7 m ± 1.4 m. Only three of 17 nests were in snags (Craig and Trost 1979).

Several researchers have studied direction that nest tree cavities and nest boxes face. As noted above, Balgooyen (1976) and Rohrbaugh and Yahner (1997) showed nest holes faced east and southeast more often than expected. Stys (1993) found that kestrels used nests with southwesterly aspects less than expected, but all other directions were used in proportion to their availability. Raphael (1985) tested Balgooyen's data versus 105 independent samples of northern flicker and Lewis' woodpecker (*Melanerpes lewis*) nests. It was found that available cavities were most often facing a northerly direction whereas occupied kestrel nests most often faced east – northeast. Therefore, Balygooyen's original finding was supported (Raphael 1985). The hypothesis behind nests facing eastward involves protection from incoming weather and use of active solar heat (Balgooyen 1976).

In areas where trees and snags are not available for nest sites, kestrels readily occupy nest boxes (Hamerstrom et al. 1973, Stys 1993, Rohrbaugh and Yahner 1997). In Pennsylvania kestrels most frequently used boxes with high nestling light intensity (amount of light penetrating the box), and boxes unobstructed by foliage. Occupied nest boxes were associated with extremely open habitat father from forest than unused boxes. Boxes that faced southeast were used more frequently than expected (Rohrbaugh and Yahner 1997).

Clutch Initiation And Size

Johnsgard (1990) summarized several studies regarding clutch initiation and size in kestrels. Eggs are laid on alternate days (1 per 24-72 hour period). Mean clutch size ranges from 3.6 – 4.7 eggs. Incubation is divided between the sexes with the male providing 15 – 20% of total time spent on the clutch. The incubation period lasts 29 – 31 days. Hatching occurs over a 3 – 4 day period, suggesting that incubation does not begin until all eggs are laid.

Parental Care

The female continues to brood the newly hatched chicks for one to two weeks after emergence (Stys 1993). Once the chicks can thermoregulate, the female assists the male in feeding duties. Food is provided the young for several weeks post fledging (Stys 1993).

Mate And Site Fidelity

The kestrel is thought to be monogamous. However, some studies suggest that promiscuous matings are common in the early breeding season as females move among several males' territories (Johnsgard 1990).

In Wyoming, a pair of kestrels was found to have occupied the same nest snag for six consecutive years. In Utah and California, kestrels also showed a certain degree of philopatry, occupying the same nest site for up to three consecutive years (Johnsgard 1990).

Demography

Life History Characteristics

Average clutch size ranges between 3.6 – 4.7 eggs. Kestrels reproduce at one year of age.

Survival And Reproduction

Nest success varies regionally. A study in Idaho reported 81% nest success, while a Pennsylvania study found only 41% success (Craig and Trost 1979, Rohrbaugh and Yahner 1997). Studies specific to nest box success have shown similar ranges of reproductive success. Hamerstrom et al. (1973) reported an average of 67% success in nest boxes in central Wisconsin. At Hawk Mountain Sanctuary (PA) nest boxes showed success rates between 44 – 63% (Klucsarits et al. 1997). High nesting and fledging rates are probably attributable to efficient parental defense (Johnsgard 1990).

Double brooding has been reported in Utah, Idaho, and Colorado (Stahlecker and Griese 1977, Haney 1995, Steenhoff and Peterson 1997). Kestrels commonly produce a second clutch if the first is destroyed early in the nesting season (Wheeler 1992).

Social Patterns For Spacing

Johnsgard (1990) summarized several studies on kestrel densities and home range sizes. In Utah, kestrel density ranged between 1.2 – 1.7 breeding pairs per km^2, while Illinois had 0.75 pairs per km^2. Home ranges also show variable sizes in different geographic locations. Utah had the smallest reported home ranges (0.68 – 0.81 km^2), while Wisconsin had the largest (109 ha). Variability in densities and home range size is probably attributable to differences in nest site and prey availability.

Local Density Estimates

No information is available regarding density estimates of kestrels in the Black Hills. Within the BHNF kestrels are present, but probably not in great abundance. The BBS reports that there are probably less than 0.1 kestrels per route surveyed. South Dakota and the BHNF fall entirely within the range of the kestrel. Low abundance may indicate either sub-optimal habitat or sub-optimal survey coverage. Kestrels have been reported as “fairly common” along roadsides throughout the Black Hills, especially along edges of meadows and rangelands (S. Mohren per. comm.).

Limiting Factors

As a neotropical migratory bird, kestrels are susceptible to many factors throughout their range. On breeding grounds, nest trees and snags are of particular importance. In areas where snags are cut down, nest sites and hunting perches may be limiting. In addition to snags, edge habitat is required for kestrel habitation. Alteration of forest/grassland ecotones may limit breeding habitat.

Community Ecology

Predators And Relation To Habitat Use

Predation on kestrels is poorly represented in the literature. Larger raptors are probably the main threat to kestrels with *Accipiter* spp. possibly posing the greatest threat. Balgooyen (1976) showed that the majority of defensive attacks by adult kestrels were on other hawks. Within nests, mammalian predators may influence young and adult survival.

Competitors

The northern flicker, Lewis' woodpecker, Williamson's sapsucker (*Sphyrapicus thyroideus*), European starling (*Sturnus vulgaris*), mountain bluebird (*Sialia currucoides*), screech owls (*Otus* spp.) and chipmunks (*Eutamias* spp.) all compete with kestrels for nest cavities (Balgooyen 1976).

Bechard and Bechard (1996) suggest that the kestrel can out-compete starlings for nest boxes. Their study showed that over a six-year period in Idaho, kestrels increased occupancy of nest boxes from 67% to 100% over starlings. Thus if starlings are present in the BHNF they probably pose little competition for kestrels.

Resource competition is vague throughout the literature. Several raptor species including northern harriers (*Circus cyaneus*), short-eared owls (*Asio flammeus*), red-tailed hawks (*Buteo jamaicensis*), and Swainson's hawks (*Buteo swainsoni*) all share habitat preferences with the kestrel, therefore it may be reasonable to assume that some competition occurs for prey items.

Parasites And Diseases

Several external and internal parasites have been reported in kestrels. *Carnus hemapterus*, a parasitic fly was reported in nest cavities in California, but did not appear to have detrimental effects on the chicks (Balgooyen 1976). Internally, blood parasites caused increased stress to incubating females in Saskatchewan (Dawson and Bortolotti 2000). *Trichinella pseudospiralis* were shown to alter hunting techniques in kestrels in Ontario; infected birds hunted more on foot than on the wing (Bombardier and Rau 1991).

Risk Factors

Risk factors facing American kestrels in the Black Hills region may include timber harvest and fire suppression. These activities have the potential to reduce breeding, nesting and foraging habitat in the BHNF.

Fire is an important component of forest and grassland ecology and can naturally enhance kestrel habitat. Kestrels rely on forest/grassland ecotone habitats for hunting and snags for nesting. Fire naturally creates a patch mosaic with a higher degree of edge along which kestrels hunt. Also, fire creates snags, which if left standing provide nest and perch sites. Balgooyen (1976) suggests that post-fire forests attract woodpeckers, which create nest cavities that may eventually support kestrels. Suppressing fires may over time limit nest sites and cause increased understory fuel loads that have the potential to burn out of control. However, the severity of wildfires on a species such as the kestrel that relies on open meadows and rangelands may be negligible.

Response To Habitat Changes

Management Activities

Timber Harvest

The greatest risk of timber harvest is in cutting down large diameter trees and snags used for nesting and perching. Clear-cutting as a silvicultural technique will likely not have a large effect on kestrels because they do not use contiguous forest habitat types. It is unlikely that clear-cutting within the BHNF will create openings large enough to support kestrels. Stys (1993) suggested that kestrels in Florida were observed in openings ranging between 25-75 ha. Clear-cuts within the BHNF are normally less than 2 ha and can be up to 4 ha. Mature stands of ponderosa pine (*Pinus ponderosa*), and quaking aspen (*Populus tremuloides*) that adjoin meadows and range lands are likely important to breeding kestrels in the BHNF. Thus, if these areas are impacted it could be damaging to kestrels, especially if snags are not left as nest sites.

The final environmental impact statement for the BHNF breaks down the commercial harvest methods to be implemented in acres per year for 10 years after the plan takes effect (USFS 1996).

The preferred alternative (G) calls for the following treatments:

TREATMENTS	ACRES
Commercial Thinning	1,700
Seed Cut	15,600
Overstory Removal	6,100
Clear Cut	0
Patch Cut	200
Hardwood Restoration	500
Seed Tree Cut	300
Meadow Restoration	1,000
Selection	100
Salvage	0
TOTAL	**25,500**

Commercial harvest is comprised of several different methods of harvest. "Commercial" implies that trees are within "utilization standards and may be sold for profit. Trees greater than 9 inches DBH may be utilized as sawtimber, and trees between 5 and 8.9 inches DBH may be utilized as products other than logs" (USFS 1996). Commercial thinning is simply the removal of trees within stands that are overstocked and where growth has been slowed because of competition with other trees. Shelterwood cuts are done in two steps. Step one involves removal of all trees except those that will be used as seed trees to regenerate the stand. Step two is overstory removal and involves removing those seed trees after regeneration has begun. In both steps, snags may be left. Seed-tree cuts leave the fewest trees per acre after manipulation. Ten or fewer trees are left per acre throughout the stand and no over story removal occurs. Patch clear-cutting involves area of 10 acres or less and designed so that seed dissemination will occur evenly across the cut area.

Harvest methods proposed, focus on thinning, opening the forest and creating uneven-aged stands. Based on the literature these methods have the potential to enhance rather than detract from kestrel habitat in the BHNF. As kestrels generally forage on edge and open habitats, timber harvest in general may not affect them as much as interior forest bird species. Patch cuts potentially could create ecotone habitats that should be suitable for kestrel foraging. With most timber harvest methods mentioned, it is important for snags to be considered for protection as nest sites.

Recreation

Kestrels are tolerant of human presence. Frequently they are seen perching along busy roadways. They also nest in occupied buildings. Recreation within the BHNF will probably not have many detrimental effects on kestrels. Most recreation probably does not occur in areas where the kestrel is present, for example in meadows and rangelands along the periphery of the Forest. Off-road vehicles will probably not disturb kestrels. Campers have some potential to impact nesting kestrels by cutting snags that serve as nest or perch sites. The largest recreation risk may be in the potential for road kills.

According to the BHNF Forest Development Road System (USFS 1996), the preferred alternative (G) calls for 277 miles of road construction, 139 miles of road obliteration, and 34 miles of roads converted to motorized trails in the first decade after the forest plan is initiated. This converts to a net increase of 104 miles of roads over a ten-year period. This may represent little impact on kestrels in the BHNF.

Livestock Grazing

No studies were identified that directly addressed the impact of livestock grazing on kestrels. Grazing may however have impacts on kestrel prey species. Studies show contradictory results, which may be attributable to geographic variation and differences in vegetational communities the studies looked at. In Idaho no significant differences were found between small mammal abundance on grazed or ungrazed sites (Johnson 1982). Rather, differences in abundance were attributed to topography and soil type. In a tall-grass prairie setting in Kansas, there was a variation in the response of small mammals to cattle grazing (Clark et al. 1989). Deer mice avoided ungrazed and unburned areas, while prairie voles (*Microtus ochrogaster*) and Ellitot's short-tailed shrew (*Blarina hylophaga*) were most abundant in ungrazed and unburned areas. In Utah, small mammals were found to respond to grazing at a macrohabitat scale (areas > 100 ha) versus patch scales (< 1 ha) (Rosenstock 1996). At the macrohabitat scale, small mammals were found to have 50% greater species richness and 80% higher abundance. Deer mice (*maniculatus*) were most abundant on grazed sites. Elliot's short-tailed shrews and prairie voles were most abundant on ungrazed sites. White-footed mice (*Peromyscus leucopus*) were most abundant in grazed and burned sites.

The studies cited above show differing results. Two showed small mammal abundance increased in ungrazed areas, with some species exceptions. One study showed no difference between ungrazed and grazed sites. It is difficult to infer what the effect might be on BHNF lands. We can assume that overgrazing will be a detriment to small mammal populations. Moderate amounts of grazing may produce similar effects to Clark et al. (1989) where some species may increase in grazed areas while others will seek out ungrazed areas.

Mining

Mining has the potential to impact kestrels. Downstream from a mine along the Coeur d'Alene River (ID) mice and voles were found to contain high lead levels. Raptors were tested for lead in the blood and kestrels showed the highest levels of four other raptor species (Henny et al. 1994). Lead levels were not high enough to cause decreased reproductive success in adults or decreased survival in chicks, but they were high enough to suppress hemoglobin levels in the blood.

As silver and gold have historically been mined in the Black Hills, tailings may continue to leach into streams and rivers of the area. This has the potential to accumulate metals in raptors such as kestrels.

A Pennsylvania study looked at raptor use of reclaimed surface mines. It was found that these areas could be important for migrating raptors, as they held populations of mice and voles (Yahner and Rorhbaugh 1998). Though it was noted that several species of grassland raptors used these areas, no mention of potential accumulations of metals or other contaminants was made.

Prescribed Fire

Kestrels may respond favorably to prescribed fires in the BHNF. A Texas study found that wintering American kestrels increased in number immediately after a prescribed burn (Chavez-Ramirez and Prieto 1994). Pre and post-burn surveys were preformed to count grassland raptors. Kestrel numbers increased positively but were insignificant ($P > .05$).

Fires set to clear understory and to create nest snags and perches may enhance kestrel breeding and foraging habitat. Like fires set in forest settings, fires in grasslands also clear out understory and allow for fresh grasses and forbs to emerge. However, problems may arise if fires burn too hot; snags may actually be destroyed. Horton and Mannan (1988) found that prescribed fires burned nearly half of the ponderosa pine snags > 15cm dbh in their Arizona study area. This high proportion suggests that burning could negatively affect cavity-nesting birds such as kestrels. There are three notable caveats to these findings. First, under repeated burning, fires will decrease in intensity, and burn fewer snags. Second, live trees killed by burns will over time replace lost snags. Lastly, forest and edge birds occurring in areas that have historically burned will have evolved to cope with fire. Thus the idea that prescribed burns will directly negatively affect kestrel nesting sites is arguable.

An indirect positive effect of prescribed burns on kestrels may be in the response of prey species, such as deer mice, to burning. A study in the Black Hills showed that deer mouse numbers significantly increased during the first post-fire summer (Bock and Bock 1983). It is noted that during the second post-fire summer, numbers of mice declined to previous levels, or in some cases lower levels. This rise and fall effect was probably due to an increase in some unmeasured variable that the fire created. When this variable was depleted the abundance of deer mice declined. As kestrels have been shown to prey on deer mice, prescribed burns may indirectly temporarily have a positive effect on them in BHNF.

Kestrels primarily hunt in grassland and edge habitats. Grasslands and forests of the Black Hills region have historically burned, so mammals and birds that inhabit these areas have evolved with these events. Prescribed burns should not negatively effect kestrels or their prey.

Fire Suppression

Fire may naturally enhance kestrel habitat. Suppressing fire may ultimately affect nest site availability, and amount of foraging habitat available. Balgooyen (1976) found that significantly more kestrels nested in burned forests than on a sagebrush/forest edge. Fire will weaken or kill trees, resulting in snags, which may become available for kestrel nest sites. In a landscape that has been fire-suppressed, snags may become limiting. Also where fire has been absent, forests become dense and may develop into "dog-hair" stands. These areas are unsuitable for kestrel nesting habitat because of lack of large-diameter trees for nesting, and lack of open understory for foraging. Ultimately fire suppression may increase the chances of large-scale uncontrollable fires. The effects this could have on kestrel habitat are likely varied.

Non-Native Plant Establishment And Control

Information was not found describing the effect of non-native plants on kestrels.

Fuelwood Harvest

Depending on the amount and condition of trees that are taken, fuelwod harvest has the potential to positively or negatively affect kestrels in the BHNF. Removal of snags and live trees containing cavities will have obvious negative effects. Fuelwood harvest techniques that consider the ecology of cavity-nesting birds such as kestrels can enhance their habitat. One study concluded that kestrels in southwestern Idaho experience their highest nesting success within salvage-logged sites, with a density of five large snags (>53cm dbh) per ha (Saab and Dudley 1998). In addition, fuelwood harvest has the potential to thin overgrown stands of forest, making them usable for foraging and nesting. Fuelwood harvest techniques that take kestrel ecology and habits into account will have little impact on kestrels and may enhance their habitat. Removal of snags and coarse woody debris, which may provide cover for prey species, from clear-cuts or other fuelwood harvest sites has the potential to reduce numbers of kestrels in the area.

Natural Disturbance

Insect Outbreaks

Insects with the capacity to impact kestrels in the Black Hills include mountain pine beetles (*Dendroctonus ponderosae*) and grasshoppers (Orthoptera spp.). Pine beetles kill trees within the BHNF, creating nest snags and potentially opening up forest patches that can be utilized by kestrels for nesting and foraging.

Although small mammals and birds make up the largest percentage of kestrel diet, invertebrates, such as grasshoppers, can be a significant food source. Balgooyen (1976) found that grasshoppers became an important food item to kestrels in California from midseason (breeding) to fall departure. Grasshoppers may benefit from drought conditions and fire-scorched soils that mirror drought conditions. Grassland soils tend to harbor large stores of grasshopper eggs. In drier times, these eggs are able to hatch, possibly because certain hydrophilic bacteria are not present, which suppress the viability of the eggs (Knight 1994). An outbreak of grasshoppers in the BHNF would likely benefit kestrels with an increase in food availability.

Wildfires

No information has been published specifically on the effect of wildfires on kestrels, however some effects can be speculated. In most of the Black Hills, with the exception of the Wind Cave National Park and Devils Tower areas, a fire suppression regime has been in place (Knight 1994). In areas where prescribed burning has taken place the forests generally mirror pre-settlement environmental conditions (Knight 1994). In areas where fire suppression has been implemented, ponderosa pine forests are usually thicker, sometimes developing into dog-hair stands. Younger trees also persist and start to invade grassland areas. Also, in fire-suppressed forests there are an abundance of understory plants and coarse woody debris. Therefore, when a wildfire breaks out the fire tends to be substantial and burn very hot. Wildfires in the Black Hills occurred every 5-25 years in pre-settlement times (Bock and Bock 1983, Knight 1994). Frequent fires kept fuel supplies down to a level where fires would burn cooler, creating surface fires, as opposed to crown fires. Surface fires kill young ponderosa pine saplings, and spare older trees with thicker, protective bark. As the Black Hills have been fire suppressed for many years, the potential for large, hot fires has increased.

Fires do, however, create a patch mosaic on the landscape (Knight 1994). These patches can develop into hunting and nesting habitat for kestrels. Overall, the effect of wildfires will depend on the size of the event. It could be argued that large fires that create more open areas within the forest could be beneficial to kestrels. Small fires that create small openings in the forest will probably not have impacts on kestrel nesting or foraging sites.

Wind Events

In general kestrels use edge habitats for nesting and foraging. Therefore, a wind event that topples large sections of contiguous forest will probably not affect kestrels at all. Sections of downed trees most likely would not be used as hunting sites or as nesting areas unless larger expanses of grassland or other open habitats are available nearby.

Other Weather Events

Because the kestrel has evolved in the northern hemisphere where stochastic weather events commonly occur, it is unlikely that extreme weather events will affect their viability. Extreme conditions can occur during the early spring when kestrels return to breeding areas. Ice storms, extreme cold and heavy, wet snow for extended periods will likely stress kestrels but in the long run should have no great effect.

SUMMARY

The American kestrel is the smallest and most common of the North American falcons. They range from the tree line in Alaska to the southern tip of South America. Kestrels are able to exploit a variety of different habitats as long as edge and open grasslands are featured in the landscape. Edge is used as nesting and foraging habitat and grassland or other open habitats are used for foraging. As secondary cavity-nesters, kestrels rely on flickers and other woodpecker species to provide them nest holes.

Prey items generally consist of small mammals, birds and invertebrates such as beetles and grasshoppers. It has been suggested that prey is taken in proportion to availability. For example, in California kestrels fed heaviest on small mammals and birds early in the brooding season and switched to invertebrates from mid-season to fall departure (Balgooyen 1976).

The kestrel is a partial migrant. Birds in the northern part of the range migrate, while more southern populations are less migratory or resident. Band recoveries suggest that birds nesting farthest north migrate farthest south. Males have been shown to winter slightly farther north and to arrive on breeding grounds earlier than females (Arnold 1991).

Factors most limiting to kestrels may be nest cavities, suitable prey, perches, and low open vegetation for foraging. Based on the ecology of the Black Hills only low open vegetation may be limiting on BHNF lands. In the past several years fires have burned through the BHNF. Snags for nest sites should not be limiting. Along forest edges and roadways that travel through grassland or pastureland, perches will not be limiting. There is little reason to believe that prey items would be limiting to kestrels in the BHNF. Kestrels should be common on BHNF lands where large meadows exist within the interior of the forest, and along the periphery of the Forest, which borders range and grasslands.

Few human impacts should exist on kestrels in the Black Hills. Recreational activities such as hiking, camping, hunting, fishing and all-terrain vehicle use probably will not disturb kestrels enough to cause them to abandon an area. The largest human threat is likely along roadways. A Florida study found vehicles to be the cause of 52% of kestrels found dead, injured or incapacitated (Stys 1993).

Management techniques such as prescribed fire, fire suppression and fuelwood harvest have the potential to impact kestrels both positively and negatively. Kestrels have evolved with fire and rely on its effects in several ways. Nest snags and hunting perches can be created by fire, prey availability can be affected by fire and foraging areas can be created by fire. Because kestrels have evolved in northern climates, stochastic weather events should only have short-term impacts on local populations.

REVIEW OF CONSERVATION PRACTICES

Management Practices

Nest boxes are perhaps the most successful management technique implemented for kestrels. In many parts of their range nest sites are limiting. Nest boxes can increase numbers of kestrels and productivity. In central Wisconsin Hamerstrom et al. (1973) found only two natural nests over a five-year period, which produced 5 young. Of 50 nest boxes in the area, 8 – 12 were used annually and produced over 200 young during the same time period. Similarly, researchers in Idaho found good kestrel habitat, but few birds due to lack of nest sites. Nest boxes were placed 0.8 km apart on a grid of 100 km^2 (Bechard and Bechard 1996). Sixty nest boxes were placed in the study area in 1986 and by 1993 observed 100% occupancy by kestrels. Similar results were found in Montana and Wyoming. Nest sites were found to be limiting and when nest boxes were placed, occupancy by kestrels was 92.9% (Wheeler 1992).

Balgooyen (1976) recognized that along with nest sites, perch sites were an important component of kestrel ecology and could be limiting. Wolf et al. (1999) used supplemental perches to attract kestrels and other raptor species to their study area in Oregon. Kestrels were detected during 28% of observation periods before perches were built and were observed 55% of the time after perches were built. Kestrels were present at control sites only four times.

Although nest boxes and supplemental perches appear to be useful tools, general habitat management may be needed in some areas. Saab and Dudley (1998) suggested that in Idaho management for black-backed woodpeckers (*Picoides arcticus*) and Lewis' woodpeckers would benefit many other cavity nesting species. Both in unlogged and burned/salvaged areas, snags were found to be most productive for cavity nesting birds when they were left in clumps as opposed to singly. Attention should be paid to woodpeckers species on the BHNF as they probably produce many of the nest cavities used by kestrels.

Stys (1993) gave more explicit management recommendations for kestrels in Florida. Specifically, if an active kestrel nest was found within 0.5 km of 50 ha of suitable habitat, a 150 m buffer should be protected around both the nest site and foraging habitat. Other recommendations were offered for several other combinations of area and distance to nest sites and foraging habitats. Snags were also marked for protection. Dead or dying trees of >24 cm dbh were recommended for protection and retention of at least 1 nest tree or snag per 8 ha. Optimal perch density appeared to be 0.5 perch per ha.

The BHNF is centrally located within the kestrel's breeding range. If abundance of kestrels is low, nest site availability close to suitable foraging areas may be a cause. The management technique most likely to increase kestrels in the BHNF is construction and placement of nest boxes (figure 2) and possibly perches sites. Nest box placement should be studied to maximize kestrel occupancy. It can be speculated that most kestrels within BHNF lands are found along the boundary edges near grasslands and rangelands. These areas should be surveyed for kestrel presence and nest boxes placed accordingly. Monitoring of boxes and perches (if deemed necessary) should be conducted seasonally to determine percent occupancy and productivity. Stys (1993) gave specific directions for placement of nest boxes, which include:

(1) Place the box approximately 7 m high.

(2) Place the nest box on poles, snags, or live trees (or on utility poles if proper authorization has been received.)

(3) Place nest box in close proximity to a roost tree.

(4) The nest box should face a southerly to easterly direction.

(5) The entrance to the nest box should be unobstructed with a clear flight path.

(6) The nest box should be placed in an open area at a distance greater than 50 m from a forest edge.

(7) If a live tree must be used as a support structure, then there should be 4.5 – 6.0 m between the nest box and the lowest branch of the tree.

Models

We could find no papers directly addressing models for American kestrels. This may be because kestrels are common and widespread across their range thus, models have not been developed to predict population trends or habitat use.

Survey And Inventory Approaches

Roadside surveys have the potential to be effective techniques for finding kestrels. The BBS uses roadways as survey tracks. Observers drive 24.5-mile routes, stopping each 0.5 mile for surveys. This technique is effective for kestrels only if the routes pass through suitable habitat. There are 15 routes in the Black Hills. If these routes cut through contiguous forest, no kestrels will be seen. If the routes skirt the edge of the BHNF boundary, and larger meadows of the forest, then kestrels might be detected. In addition to BBS, surveys for kestrels in the BHNF should consist of driven routes through the suitable habitat in the Forest, and edges of the Forest boundary. Also, a concerted effort needs to be made to seek out specific areas of suitable habitat within less-accessible areas of the forest. Whether driven to, or hiked to, these areas also need to be surveyed to obtain an accurate estimate of birds within BHNF lands.

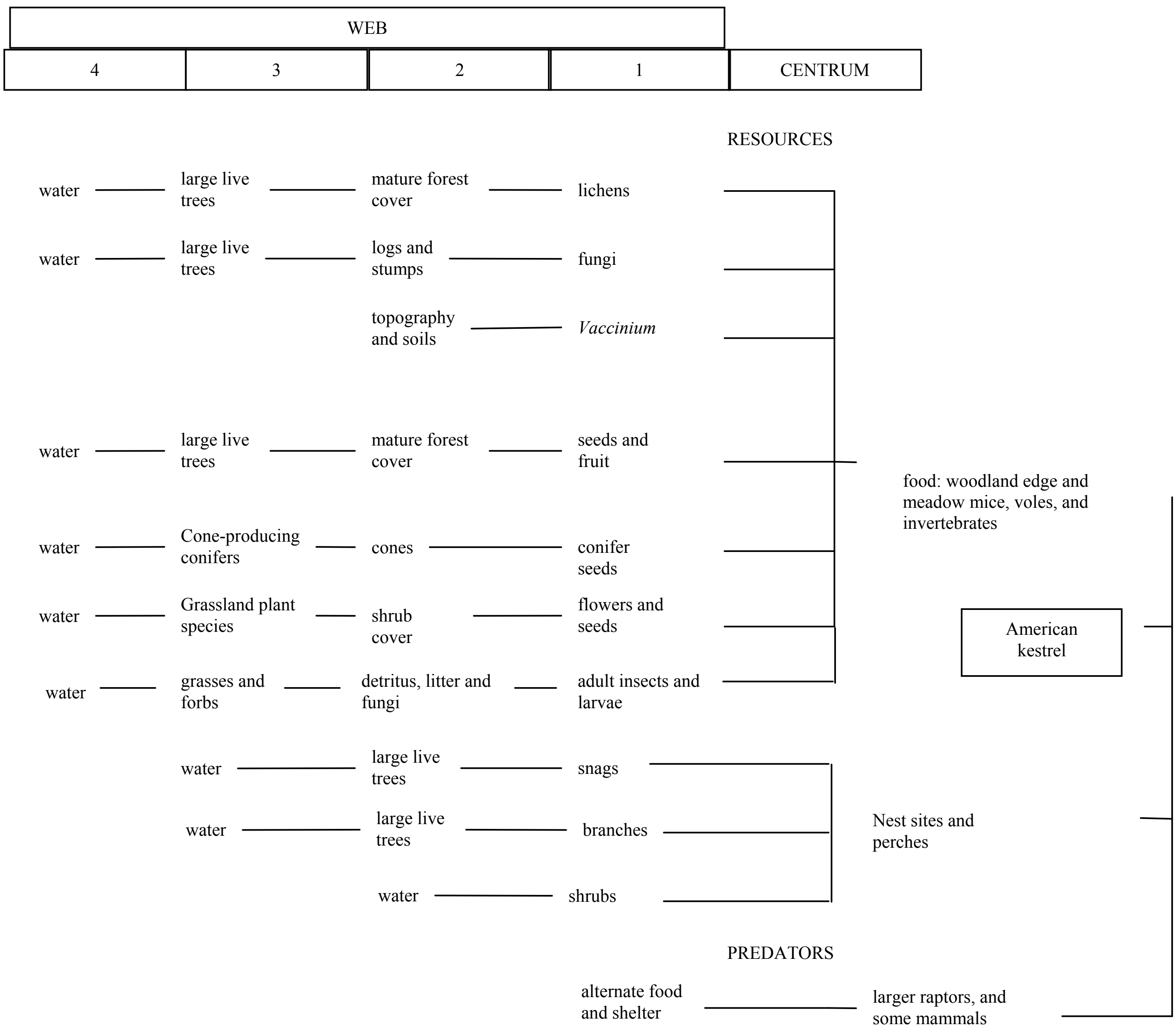
Monitoring Approaches

A determination needs to be made whether or not nest sites are limiting. Due to the fire regime and insect ecology in the BHNF they may not be. However, if they are, monitoring kestrels in the BHNF will be most successful when combined with nest boxes. Adult birds and their young should be captured and banded at the nest boxes. Kestrels exhibit fairly strong site fidelity and therefore should return to the same box or nearby boxes in following years. Therefore, monitoring occupied territories/nest sites could give a rough estimate of numbers of birds on the Forest. In addition, to BBS routes, other driving routes should be established on the Forest and driven annually to count kestrels.

ADDITIONAL INFORMATION NEEDS

Baseline information needs to be collected on kestrels in the Black Hills. Kestrel data is provided by the BBS, but is unreliable because it is only a few routes. These routes may run through the middle of the forest where there are no kestrels. First-hand information is needed from a survey of suitable kestrel habitats. Region-wide trends suggest that kestrel populations have been declining about 1% per year and this is probably true for the Black Hills too. Throughout the Forest, nest sites may not be limiting as recent fires have created good habitat for cavity-nesting birds. However nest sites in proximity to foraging areas may be limiting. Nest boxes have been proven to successfully recruit kestrels to regions where they have previously been seen in very low numbers. If it is confirmed that kestrel numbers are as low as 0.1 birds per route, then a nest box program is probably feasible. In addition if trends are proven to be declining, it may be important to identify the wintering grounds of kestrels that breed on the BHNF. This information may allow for discrimination between effects of habitat changes on breeding grounds versus changes on wintering grounds.

Figure 1. Envirogram for the American kestrel in the Black Hills



LITERATURE CITED

Arnold, T.W. 1991. Geographic variation in sex ratios of wintering American kestrels *Falco sparverius*. Ornis Scand. 22: 20-26.

Balgooyen, T.G. 1976. Behavior and ecology of the American kestrel (Falco sparverius L.) in the Sierra Nevada of California. Univ. Calif. Publ Zool. Vol. 103. University of California Press, Berkley, CA.

Bechard, M.J., and J.M. Bechard. 1996. Competition for nest boxes between American kestrels and European starlings in an agricultural area of southeastern Idaho. Pgs. 155-162 *in* D.M. Bird, D.E. Varland, and J.J. Negro eds. Raptors in Human Landscapes. Academic Press San Diego, CA.

Becker, D.M. 1987. Use of black-billed magpie nests by American kestrels in southeastern Montana. Prairie Nat. 19: 41-42.

Bergeron, D., C. Jones, D.L. Genter, and D. Sullivan. 1992. P.D. Skaars Montana Bird Distribution, Fourth Edition. Special Publication No. 2. Montana Natural Heritage Program, Helena. 116 pp.

Bock, C.E., and J.H. Bock. 1983. Responses of birds and deer mice to prescribed burning in Ponderosa Pine. J. Wildl. Manag. 47: 836-840.

Bombardier, M., and M.E. Rau. 1991. Effects of *Trichinella pseudospiralis* infections on the predatory behavior of American kestrels (*Falco sparverius*). J. Raptor Res. 25: 152.

Chavez-Ramirez, F., and F.G. Prieto. 1994. Effects of prescribed fire on habitat use by wintering raptors on a Texas Barrier Island grassland. J. Raptor Res. 28: 262-265.

Clark, B.K, D.W. Kaufman, E.J. Finck, and G.A. Kaufman. 1989. Small mammals in tall-grass prairie: patterns associated with grazing and burning. Prairie Nat. 21: 177-184.

Craig, T.H., and C.H. Trost. 1979. The biology and nesting density of breeding American kestrels and long-eared owls on the Big Lost River, southeastern Idaho. Wilson Bull. 91: 50-61.

Dawson, R.D., and G.R. Bortolotti. 2000. Effects of hematozoan parasites on condition and return rates of American kestrels. Auk 117: 373-380.

Dunning, J.B. Jr. 1984. Body weights of 686 species of North American birds. Western Bird Banding Association Monograph No. 1. Eldon Publ. Co. Cave Creek, AZ.

Farrand, J. Jr. 1988. An Audubon handbook: western birds. McGraw-Hill Book Co., New York, NY.

Ganis, G.R. 1976. American kestrel eating carrion. Wilson Bull. 88: 357.

Hamerstrom. F., F.N. Hamerstrom, and J. Hart. 1973. Nest boxes: an effective management tool for kestrels. J. Wildl. Manag. 37: 400-403.

Haney, D. 1995. Unusually early nesting record of American kestrel in central Utah. UT Birds 11: 15-16.

Henny, C.J., L.J. Blus, D.J. Hoffman, and R.A. Grove. 1994. Lead in hawks, falcons, and owls downstream form a mining site on the Coeur d'Alene River, Idaho. Environ. Monit. Assess. 29: 267-288.

Horton, S.P., and R.W. Mannan. 1988. Effects of prescribed fire on snags and cavity nesting birds in southeastern Arizona pine forests. Wildl. Soc. Bull. 16: 37-44.

Jobin, B., J. DesGranges, and C. Boutin. 1998. Farmland habitat use by breeding birds in southern Quebec. Can. Field-Nat. 112: 611-618.

Johnsgard, P.A., 1990. Hawks, eagles and falcons of North America: biology and natural history. Smithsonian Institution Press, Washington D.C.

Johnson, M.K. 1982. Response of small mammals to livestock grazing in southcentral Idaho. J. Wildl. Manag. 35: 51-53.

Klucsarits, J.R., B. Robertson, and S. Robertson. 1997. Breeding success of American kestrels nesting in boxes in eastern Pennsylvania, 1987-1994. PA Birds 11: 138-140.

Knight, D.H. 1994. Mountains and Plains: the ecology of Wyoming landscapes. Yale University Press, New Haven CT.

Luce, B., B. Oakleaf, A. Cerovski, L. Hunter, and J. Priday. 1997. Atlas of birds, mammals, reptiles and amphibians in Wyoming. Wyoming Game and Fish Department, Lander, WY.

Peterson, R.A. 1995. The South Dakota Breeding Bird Atlas. South Dakota Ornithologists' Union, Aberdeen, SD.

Raphael, M.G. 1985. Orientation of American kestrel nest cavities and nest trees. Condor 87: 437-438.

Rohrbaugh, R.W. Jr., and R.H. Yahner. 1997. Effects of macrohabitat and microhabitat on nest-box use and nesting success of American kestrels. Wilson Bull. 109: 410-423.

Rosenstock, S.S. 1996. Shrub-grassland small mammal and vegetation responses to rest from grazing. J. Range Manag. 49: 199-203.

Saab, V.A., and J.G. Dudley. 1998. Responses of cavity-nesting birds to stand-replacement fire and salvage logging in ponderosa pine/Douglas-fir forests of southwestern Idaho. Res. Pap. RMRS-RP-11. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 17pp.

Sauer, J.R., S. Schwartz, and B. Hoover. 1996. The Christmas Bird Count Home Page Version 95.1. Patuxent Wildlife Research Center. Laurel, MD.

Sauer, J.R., J.E. Hines, I. Thomas, J. Fallon, and G.Gough. 2000. The North American Breeding Bird Survey Results and Analysis 1996-1999. Version 98.1 USGS Patuxent Wildlife Research Center. Laurel, MD.

Sferra, N.J. 1984. Habitat selection by the American kestrel (*Falco sparverius*) and red-tailed hawk (*Buteo* jamaicensis) wintering in Madison County, Kentucky. Raptor Res. 18: 148-150.

Sherrod, S.K. 1978. Diets of North American Falconiformes. Raptor Res. 12: 49-121. South Dakota Ornithologists' Union. 1991. The birds of South Dakota, 2nd edition. South Dakota Ornithologists' Union, Aberdeen, SD.

Stahlecker, D.W., and H.J. Griese. 1977. Evidence of double brooding by American kestrels in the Colorado high plains. Wilson Bull. 89: 618-619.

Steenhof, K., and B.E. Peterson. 1997. Double brooding by American kestrels in Idaho. J. Raptor Res. 31: 274-276.

Stys, B. 1993. Ecology and habitat protection needs of the southeastern American kestrel (Falco sparverius paulus) on large-scale development sites in Florida. Office of Environmental Services Florida game and Freshwater Fish Commission, Tallahassee, FL.

Terres, J.K. 1980. The Audubon Society encyclopedia of North American birds. Alfred A. Knopf, New York. New York.

Toland, B.R. 1987. The effect of vegetative cover on foraging strategies, hunting success, and nesting distribution of American kestrels in central Missouri. J. Raptor Res. 21: 14-20.

Varland, D.E., R.D. Andrews, and B.L. Ehresman. 1992. Establishing a nest box program for American kestrels along an interstate highway. Iowa Department of Natural Resources. Northern Prairie Wildlife Research Center Homepage. http://www.npwrc.usgs.gov/resource/tools/kestrel/kestrel/htm (Version 16JUL97).

Wheeler, A.H. 1992. Reproductive parameters for free-ranging American kestrels (*Falco sparverius*) using nest boxes in Montana and Wyoming. J. Raptor Res. 26: 6-9.

Willoughby, E.J., and T.J. Cade. 1964. Breeding behavior of the American kestrel (Sparrow hawk). Living Bird 3: 75-96.

Wolf, J.O., T. Fox, R.R. Skillen, and G. Wang. 1999. The effects of supplemental perch sites on avian predation and demography of vole populations. Can. J. Zool. 77: 535-541.

Yahner, R.H., and R.W. Rorhbaugh Jr. 1998. A comparison of raptor use of reclaimed surface mines and agricultural habitats in Pennsylvania. J. Raptor Res. 32: 178-180.

DEFINITIONS

Ecotones – The boundary at which two habitats meet, creating areas where more than one habitat type are available to an animal.

Eurytopic - Tolerant of a wide range of habitats.

Philopatry - The tendency to remain in one locality; a group or species showing little potential to disperse.

Snag – A dead standing tree.

Statistical power –Based on sample size and resulting standard errors, the ability to detect a significant difference between subjects being studied.