PREDATION OF WATERFOWL
IN PRAIRIE BREEDING AREAS

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Preface

This document provides information about mammalian predators and predation issues surrounding management of breeding ducks in the eastern portions of the Prairie Pothole Region. Our goal was to provide resource managers information about the individual predator species, predation management tools, and address questions posed by managers regarding predation management for breeding ducks in the Region.

We divided the document into 4 parts and include several major publications related to predation issues. Each part is intended to stand independently, thus, there is some redundancy among parts. Each part provides an extensive literature section allowing readers the opportunity to further examine issues.

Part I introduces the predation issue, provides background and setting for discussion of predation management issues. Part II documents current knowledge about how individual mammalian predator species impact breeding ducks. Part III addresses several questions (topics) that resource managers provided to the authors for discussion within this document. Part IV (appendix) provides a brief description of biology and ecology of individual mammalian species that impact breeding ducks in the Region

PART I:

INTRODUCTION TO PREDATION ON WATERFOWL IN PRAIRIE BREEDING AREAS
Marsha A. Sovada

An obvious approach to population enhancement is identifying key biological factors that affect population size and recruitment, and subsequently influencing those factors in the most efficient and effective manner (Caughley 1994). For waterfowl, reducing mortality is key to enhancing recruitment rates and populations (Johnson et al. 1992). Generally, we know little about mortality rates of individual species of ducks, although we have insight to causes of mortality (see Sargeant and Raveling 1992).

Factors underlying most duck predation issues are strongly influenced by changes in habitats essential to their breeding and changes in predator populations. Such changes influence predation rates on ducks. Nesting ducks suffer from chronic deterioration and loss of critical habitats over much of their breeding range because of encroachment by agricultural, industrial, and residential developments (Sugden and Beyersbergen 1984, Petersen and Hogan 1996). Numerical and composition changes likewise have occurred among predator communities and populations in many duck breeding areas, which often adversely affected survival of duck species (Johnson and Sargeant 1977, Sargeant et al. 1993, Sovada et al. 1995). Decline in abundance or low densities of ducks may eventuate a population that is less able to withstand the normal range of predation rates (Raveling 1989). Generally, more than one factor is involved when predation negatively impacts duck populations.

Status of Populations

Since 1955, estimates of duck breeding populations surveyed in the Prairie Pothole Region (PPR) have varied from 34 million in 1956 to 12 million in 1991, when estimates for some species were at or near record low levels (Batt et al. 1989, Austin 1998). Since then, populations of most species common in the PPR, except northern pintails (*Anas acuta*) and lesser scaup (*Aythya affinis*), have recovered to levels near or above the population goals of the North American Waterfowl Management Plan (United States Fish and Wildlife Service 1998). Greenwood and Sovada (1996) discussed factors (e.g., drought cycle, habitat conditions, predator populations) contributing to the recovery of duck populations in the 1990s. Population trends among breeding ducks tend to reflect availability of ponds in spring in the PPR (Batt et al. 1989, Austin 1998), but Johnson and Shaffer (1987) presented evidence of long-term population declines in mallards (*Anas platyrhynchos*) preceding the drought of the 1980s. Bethke and Nudds (1995) indicated that declines in mallards and northern pintails during the drought of the 1980s were more severe than predicted on the basis of variation in available wetlands. Population declines of several species have been linked with low recruitment, primarily attributed to high rates of predation on eggs, but predations on adults and ducklings also have contributed (Cowardin et al. 1985, Klett et al. 1988, Sargeant and Raveling 1992, Greenwood et al. 1995). High predation rates may inhibit the recovery of duck populations when habitat conditions are favorable.

Change in Habitats and Predator Communities and the Impacts on Waterfowl Populations

In the PPR, breeding habitats have been impacted severely by conversion of grassland to cropland and wetland drainage (Sugden and Beyersbergen 1984, Miller and Nudds 1996), increasing the impact of predation on waterfowl populations (Cowardin et al. 1985, Greenwood et al. 1995, Beauchamp et al. 1996). Loss of wetlands and fragmentation of grasslands has concentrated ducks and predators in the remaining patches of suitable habitats and likely has reduced the abundance of alternative prey species

used by predators for food (Cowardin et al. 1983, Sargeant and Raveling 1992). Because many species of prairie ducks occupy breeding habitats based on availability of wetlands in spring (Johnson and Grier 1988), they are at great risk to predation in areas where cropland is abundant because they are forced to nest in the scant patches of nesting cover that remain. Greenwood et al. (1995) estimated that nest success in the PPR of Canada decreased about 4 percentage points for every 10 percentage point increase in availability of cropland.

Habitat changes and human activities have affected the distribution and abundance of some predators in the PPR (Sargeant et al. 1993, Greenwood and Sovada 1998) and in a very real sense, populations of several duck predators have benefited from human settlement. The replacement of larger predators (e.g., gray wolf *Canis lupus*, coyote *C. latrans*) by smaller Amesopredators@, which often are more numerous, has been detrimental to nesting ducks (Johnson and Sargeant 1977, Sargeant et al. 1984, Sargeant et al. 1993). Particularly significant has been the increase in numbers of red foxes (*Vulpes vulpes*), principal predators of nesting ducks and eggs (Johnson et al. 1989, Sovada et al. 1995). Raccoons (*Procyon lotor*) have benefited from the increased availability of grain, buildings, and trees to the prairies. Franklin's ground squirrels (*Spermophilus franklinii)* also have increased numerically and expanded their range in response to changes in habitats following human settlement in the region (Sargeant et al. 1993, Greenwood and Sovada 1998). Increases in woody habitats and protection from human caused mortality also may have contributed to changes in the avian predator community (Murphy 1993, Sargeant et al. 1993). Red-tailed hawks (*Buteo jamaicensis*), great-horned owls (*Bubo virginianus*), crows (*Corvus brachyrhunchos*), and magpies (*Pica pica*) have expanded their ranges in the PPR (Houston and Bechard 1983, Murphy 1993, Sargeant et al. 1993). All these changes in predator populations likely have contributed to increased rates of predation on breeding ducks in the PPR.

Predation has a major impact on populations of ducks in the PPR. Johnson and Sargeant (1977) demonstrated that predation on nesting mallard hens by red foxes may be responsible for the imbalanced sex ratio common in mallards. Murphy (1993) and Greenwood et al. (1995) reported a high proportion of female remains among dabbling ducks killed by several mammalian and avian predator species in the PPR of Canada. Analyses of nesting studies indicate that long-term nest success of ducks in the PPR has declined (Beauchamp et al. 1996), likely due in part to conversion and fragmentation of critical breeding habitats and changes in predator communities. Reported nest success rates are often below the levels of 15B20% thought to be necessary for population stability among the common species of dabbling ducks (Cowardin et al. 1985, Klett et al. 1988). Most studies report that >70% of nest failures are attributed to predation.

Predation Management

A variety of methods have been tried or suggested for reducing effects of predation on nesting ducks in the prairie (see reviews by Clark et al. 1996, Greenwood and Sovada 1996). Management approaches fall into 3 general categories: (1) restoration and protection of habitats critical to nesting ducks, (2) isolation of nests from predators, and (3) removal of predators by lethal methods.

Predation is most severe where a large proportion of the landscape has been converted to cropland. Greenwood et al. (1995) found that nest success in the PPR is correlated positively with the amount of perennial grassland in the landscape. Because of this, when possible, managing predation should focus on protection and restoration of grassland that result in large areas of grasslands. Likewise, areas where large tracts of grassland remain intact should be protected from conversion to cropland or fragmentation. Reynolds et al. (1996) suggested that areas with greatest potential for management to improve success of nesting ducks are those areas where wetlands are most abundant.

Intensive management designed to isolate nests from predators can be grouped into methods that physically separate or conceal nests from predators, those that alter foraging behavior of predators or their food availability, and those methods that affect predator distribution and abundance (Greenwood and

Sovada 1996). Most methods are aimed at protecting the nesting hen and eggs from mammalian predators; few focus on avian predators or enhancing survival of ducklings. Methods appropriate at a local scale include those that isolate nests (e.g., nesting structures, barrier fences, moats). Although such methods are effective in increasing nest success, they can be resource and labor intensive (Lokemoen 1984). Other methods that alter predator foraging (e.g., conditioned taste aversion, supplemental foods) have proven to be less effective (Greenwood et al. 1998, also see Greenwood and Sovada 1996). Methods that influence predator distribution, such as managing canid populations to favor coyotes and reduce red fox populations, have potential to positively affect nest success over large areas of the landscape (Sovada et al. 1995). Coyotes also may suppress raccoon densities (Johnson et al. 1989). Badgers (*Taxidea taxus*), a species associated with large areas of grassland, may suppress striped skunk (*Mephitis mephitis*) populations (Johnson et al. 1989). Numerical reduction of predators with reproductive inhibitors also has been suggested, but this approach is not likely to be acceptable because of cost and difficulty in accomplishing goals (see Greenwood and Sovada 1996).

Several studies have shown lethal methods (e.g., toxicants, traps, shooting) to be effective in controlling predators and increasing duck nest success (Duebbert and Lokemoen 1980, Greenwood 1986, Sargeant et al. 1995, Garrettson et al. 1996). Use of toxicants to reduce predator numbers could be especially effective over large areas of the landscape, but effects on non-target species are of great concern. Although predator control is effective, there are drawbacks. Predator control often is opposed by the public, even to protect endangered species, and will be difficult to implement because of social constraints (Goodrich and Buskirk 1995). Toxicants, the most effective control method, require an extraordinarily expensive registration process, deterring the development of new control agents. Other issues to consider with lethal control include humane treatment of animals, ethical concerns, and anti-hunting and anti-trapping sentiment (Kirkpatrick and Turner 1985). To enhance duck production, predators would have to be controlled each spring at a time when fur has little value. Thus, there are serious ethical concerns for wildlife managers who would be forced to advocate wasting a valuable fur resource to enhance production of ducks to be harvested by other users. Finally, there are few long-term benefits because redistribution, dispersal, and compensatory reproduction by predators require extensive control of predators every year.

Recommendations. In the unstable and disturbed environment of the PPR, where wetland conditions change continually, the challenge is to know when, where, and how to apply existing options to manage nesting habitat and predation. To make informed decisions, managers need information on habitat conditions, predator community composition, and nest success rates at the landscape scale. Maintaining waterfowl breeding habitats is paramount to the long-term welfare of waterfowl populations. Maintaining and increasing critical breeding habitats can be accomplished through purchase, lease, and restoration of wetland and grassland areas, encouragement of beneficial public policy, and working with landowners to encourage beneficial farming practices (see United States Department of Interior, Environment Canada, and Desarrolo Social México 1994). All of these actions improve characteristics of the landscape for ducks and other wildlife species and likewise improve soil and water conservation.

Management to enhance wetland and upland habitats for nesting ducks is likely to be most beneficial to ducks when applied in areas where nest success is greatest (Greenwood et al. 1995) and this occurs generally near large tracts of grassland.   In areas where nesting habitat is scant and predation rates are high, it makes little sense to attempt to attract more ducks through wetland restoration or to increase nesting habitat through purchases or leases of small tracts of land. Some landscapes are so severely altered that it would be nearly impossible to restore enough nesting habitat to return nest success to sustainable levels without use of other means as well. This is likely to be the situation in many areas of Minnesota and Iowa. Under severely altered conditions, it may be more appropriate to isolate areas of nesting habitat from predators (e.g., barriers) or reduce predator populations through specially permitted lethal control.

Knowledge of how predators respond to managed habitats (e.g., configuration of grassland patches, wetlandвgrassland composition in landscapes) could help direct managers in their efforts to create more secure nesting habitats. It may be possible to ⌐compose¬ favorable grasslandвwetland patterns on a landscape scale in collaboration with farm programs (Phillips et al. 2003). Knowledge of how predator species interact as a community could provide insight to predation management options thus far not identified.

Concluding Remarks

The vision of the North American Waterfowl Management Plan (NAWMP) is focused clearly on conservation of biological diversity and a landscape approach to management, recognizing that the perpetuation of waterfowl populations depends on long-term protection, restoration, and management of critical habitats (United States Department of Interior, Environment Canada, and Desarrolo Social México 1994). The NAWMP is intended to provide benefits to the overall environmental fitness of affected ecosystems largely through habitat conservation. Within the NAWMP, predation issues are addressed as symptoms of inadequate habitat management, yet it is recognized that habitat improvements alone are insufficient to effectively manage predation in all situations. Intensive predator management is a warranted and important alternative when habitat management alone is inadequate.

Clearly, intensive predator management, especially extensive predator removal, can successfully enhance duck productivity. However, in an era of limited resources, expending funds on intensive predator management necessarily competes with habitat acquisition, management, and enhancement activities, the emphasis of the NAWMP. Such economic trade-offs must be considered and incorporated if predation management is to be applied at more than a site-specific scale. Long-term solutions transcend site-specific intensive predation management, yet we cannot dismiss the dilemma facing individual managers with limited resources, who are responsible for managing local breeding populations of ducks. To ensure biologically sound management decisions at both site-specific and landscape scales, guidance, information, and acceptable tools must be available for managers to develop suitable strategies to abate predation problems. Strategies must be tailored to each situation, but ultimately they must be integrated with long-term conservation of waterfowl. This means that predation management, even at a local scale, is usually not a substitute for habitat management.

The NAWMP provides a framework to actively manage predation (United States Department of Interior, Environment Canada, and Desarrolo Social México 1994), but evaluation is an essential component needed to assess effectiveness of predation management. If the management goal is to enhance waterfowl production, evaluation should focus on changes in recruitment. Other measurements (e.g., number of predators removed, amount of nesting habitat planted, number of wetlands restored) are easy and appealing to document, but may have little relation to actual number of offspring recruited (Sargeant et al. 1995, Greenwood and Sovada 1996).

Although predation is a natural component of waterfowl population biology, both environmental and anthropogenic alterations have changed the magnitude and importance of its impact on waterfowl populations. Predation issues are controversial and complex, because they raise questions involving humane treatment of animals, anti-hunting and anti-trapping sentiments, and ethical concerns about management of one harvested species in favor of another. The effects of altering predator communities must be examined if intensive predator management programs are to be defended adequately. Innovative methods of population management need to include an element of flexibility to allow decision making to respond to the dynamic nature of factors influencing breeding success. Ultimately, predation management must not only solve waterfowl recruitment short falls, but also must be acceptable to the public, whose support is critical to the maintenance of waterfowl populations and contributes to long-term management goals.

1999). Nests located in such areas are most likely to be encountered by long-tailed weasels, but both species of weasels typically forage in upland habitats in pursuit of small mammals.

Franklin's Ground Squirrel

The Franklin's ground squirrel (*Spermophilus franklinii*)*,* the only rodent believed to affect duck production in the Prairie Pothole Region, is one of the least-studied predators of duck eggs and ducklings in the Region (Sowls 1948, Greenwood 1986, Sargeant et al. 1987). Distribution is typically Ɑdiscontinuous and sparse@ (Murie 1973), but populations can be locally abundant. Therefore, the Franklin's ground squirrel is only considered an important predator of duck eggs locally (Sowls 1948, 1955; Greenwood 1986; Sargeant et al. 1987).

The Franklin's ground squirrel is the most omnivorous of the ground squirrel species that inhabit the PRAIRIE POTHOLE REGION. The impact of this species on ducks is primarily as an egg predator, although they may take ducklings (Sowls 1948, 1955, Sargeant et al. 1987). Unlike larger predators, destruction of an entire clutch by ground squirrels probably is uncommon. Rather, they more typically take some eggs out of individual nests resulting in reduced clutch size (Sargeant et al. 1987). Sowls (1948) attributed mortality of some ducklings found along roads to Franklin's ground squirrels, although he did not directly observe a predation event; he also found duckling remains at burrows of ground squirrels. He suspected ground squirrels might take individual ducklings that had become separated from a brood.

Sowls (1948) attributed 12% of 95 depredated nests to Franklin's ground squirrels. Based on his field data and review of other duck nesting studies from many areas in the central United States, he concluded that Franklin's ground squirrels are a localized problem, Ɑcausing serious losses only during certain times and certain places. Marshy areas with wooded borders provide most ideal situations for ground squirrel predation upon duck nests.@

Franklin's ground squirrels prefer dense or brushy habitats (Choromanski-Norris et al. 1989), thus grasslands managed for waterfowl production are well suited to this species*.* Patterns of habitat use by Franklin's ground squirrels in central North Dakota could not be explained by vegetation height and density or by litter depth (Choromanski-Norris et al. 1989). These authors hypothesized that northern pocket gopher (*Thomomys talpoides*) burrow systems had a major, but indirect effect on habitat use, because ground squirrels used abandoned burrow systems.

Franklin's ground squirrels tend to be secretive and they can easily go undetected without trapping to verify their presence. Their vocalization is similar to that of the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), but slightly deeper in tone. Experienced observers can distinguish between the calls, and vocalizations in the spring can be an indicator of presence.

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PART II:

**IMPACTS OF INDIVIDUAL MAMMALIAN PREDATOR SPECIES
ON EGGS, DUCKLINGS AND ADULT DUCKS**
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Introduction

A wide variety of interrelated factors influence the impact that mammalian predators have on ducks, including the characteristics of individual predators, population dynamics, interactions of the predator community, and the distribution and abundance of alternate prey species and the nesting ducks. Moreover, adaptations of ducks to predation influence the vulnerability of ducks to predation. In this section we review some factors that influence predation and examine the impacts of individual predation species on eggs, ducklings, and adult ducks.

The location and temporal characteristics associated with duck nests influence their vulnerability to individual predator species. Habitats in which nests are located influence the nest's vulnerability to individual predator species because of the behavior or typical movement patterns of the predator species. For example, duck nests in uplands (primarily dabbling ducks) are vulnerable to red fox (*Vulpes vulpes*), coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), badger (*Taxidea taxus*), weasel (*Mustela spp.*), and Franklin's ground squirrel (*Spermophilus franklinii*) (Sargeant and Arnold 1984), whereas nests overwater are vulnerable primarily to mink (*Mustela vison*) and raccoon (*Procyon lotor*; Eberhardt and Sargeant 1977, Sayler 1985). Early-initiated nests in upland habitats tend to be more vulnerable to predation than nests initiated later in the season (Johnson et al. 1989), perhaps because alternative prey (e.g., invertebrates, small mammals) are less available.

Most duck species have sufficient time and can obtain sufficient energy to renest if they lose their first nest to predation. Renesting effort varies with species. For instance, mallards have been found to renest 1В4 times (Drilling et al. 2002), whereas northern pintails (*Anas acuta*) might renest only once or rarely twice (Austin and Miller 1995). With each renest, however, clutch size declines. Thus, although nests initiated later in the season might hatch at a greater rate than nests initiated earlier (Greenwood et al. 1995), potential recruitment will be lower than if earlier nests had survived.

The mammalian species reviewed here are largely opportunistic in their foraging habits, thus their impact on local breeding populations likely will vary with abundance and distribution of alternative prey. Diets often shift seasonally in response to prey availability. Most predators encounter and take waterfowl incidental to foraging activities focused on other foods (e.g., skunks focus on invertebrates) or as a relatively small proportion of their diet (e.g., badgers, coyotes, weasels), while other predators might show more interest in waterfowl or other waterbirds as their primary prey (e.g., red fox, mink). Although there is anecdotal evidence for the indirect effect of alternative prey on nest success, very few studies have adequate data to directly document this. Nest success has been reported as positively correlated with rodent densities among years for blue-winged teals (*Anas discors*) in Iowa (Byers 1974), and for various arctic-nesting waterbirds (Summers 1986, Summers and Underhill 1987, Sutherland 1988, Bêty et al. 2002). Ackerman (2002) reported positive correlation between nest success rates of mallard (*Anas platyrhynchos*) and rodent abundance among years and among sites within years in California. These studies focused on small mammals as alternative prey to ducks; we are not aware of studies that have addressed other alternative prey (e.g., invertebrates, amphibians), which are important prey for most of the mammalian predators reviewed here. These prey types each require different sampling methods and should be monitored concurrently, thus making a comprehensive study of alternate prey challenging.

The conditions of upland and wetland habitats used for nesting also can influence predation pressure. When wetlands containing water are abundant, it is likely that nests are more widely dispersed

in both upland and wetland habitats than under dry conditions. Predators forage less efficiently on nests when they are dispersed rather than clumped in smaller areas. Furthermore, during periods of abundant precipitation, higher water levels might provide better security for nests located overwater or on islands. Likewise, during periods of abundant precipitation, vegetation growth is more robust, providing better nesting cover for ducks and possibly more abundant food resources for alternative prey. In the Canadian prairie, predation rates on nests that were initiated early were negatively related to abundance of seasonal wetlands containing water (Johnson et al. 1989). Similarly, predation rates were lower for nests initiated later in the season in areas with a large portion of semipermanent wetlands containing water. However, areas with permanent wetlands, riverine habitats, or abundant wetlands can support higher populations and wider distribution of mink, an important predator of nests, hens, and especially ducklings.

In the following sections, we address what is known about how individual mammalian predators impact nesting ducks in the Prairie Pothole Region.

Red Fox

The red fox has been identified as an important predator affecting duck production in the Prairie Pothole Region and no other predator in the region has as much potential for affecting duck populations as the red fox (Sargeant 1972, Johnson and Sargeant 1977, Johnson et al. 1989, Sargeant et al. 1984). Red foxes readily depredate nests encountered and will usually remove all eggs in the clutch, often caching them away from the nest site for consumption later (Sargeant et al. 1998). This caching behavior is instinctive and, because the foxes do not immediately eat eggs, satiation cannot diminish the behavior. Foxes might remove and cache eggs from many nests in a night of foraging. This behavior is so ingrained that there are commonly told anecdotes about foxes burying golf balls "stolen" from golf courses.

Foxes probably have a greater focus on taking adult ducks than any other mammalian predator except, perhaps minks. Field personnel might fail to detect the fox as predator of adult hens because hens often may be taken without struggle and carried away (Sargeant et al. 1998). Foxes also take ducklings, but remains of ducklings are rarely found because they usually are consumed entirely (Sargeant et al. 1973).

Species composition of adult ducks taken by red foxes generally reflects the nesting chronology and make-up of the local breeding population (Sargeant 1972, Sargeant et al. 1984, Fleskes and Klaas 1993). Vulnerability to predation by foxes is greater among dabbling ducks than among diving ducks and greater for females than for males. Females usually comprise ∃75% of dabbling duck remains found at fox dens (Sargeant 1972, Sargeant et al. 1984, Fleskes and Klaas 1993). Only 40% of diving duck remains at dens were from female divers (Sargeant et al. 1984). In general, the earlier a species nests and the more persistently it renests, the greater is its vulnerability to foxes. Hence, early-nesting species are more vulnerable to foxes than late-nesting species, and dabbling ducks are most vulnerable during wet springs when nesting effort is strongest. For instance, when species composition of ducks found dead at fox dens was compared to the local breeding population, northern pintails and mallards were found to be most vulnerable to foxes, and gadwalls and blue-winged teals the least vulnerable (Sargeant et al. 1984, Fleskes and Klaas 1993).

Predation on duck populations by foxes is positively related to fox density. The territorial characteristics of the red fox family group result in complete occupancy of nearly all land areas in the PRAIRIE POTHOLE REGION during periods of moderate to high population densities (and periods of low coyote numbers; Johnson and Sargeant 1977). During periods of low population density, areas uninhabited by foxes can be found. However, even during periods of high fox population density, individual nests are likely exposed to predation by only a single family of foxes.

Rearing dens are focal points of red fox activity and den locations might have considerable

influence on predation. Further, nutritional demands of female foxes with pups vary with age of the pups, which affects prey demands. Sargeant (1978) estimated that a typical fox family of 2 adults and 5 pups, in a typical territory of 7.8 km^2, required 18.5 kg/km^2 of prey biomass during the 12-week denning period. Pups began eating prey by their fourth week and started consuming duck eggs by their ninth week. In the PRAIRIE POTHOLE REGION, the fox denning period (April-July) coincides with duck nesting. By early to mid-June, juvenile foxes are able to destroy nests near their dens (Sargeant 1978, Sargeant et al. 1981).

Johnson and Sargeant (1977) evaluated the impact of red foxes on the sex ratio of prairie mallards, by using a simple model of mallard population dynamics and information on mallard and red fox populations in North Dakota for 1963B1973. They concluded that an imbalanced sex ratio in prairie mallards is the result of reduced female survival mainly because of predation by red foxes and that red fox predation is the major single source of nonhunting mortality of hen mallards in North Dakota. They estimated that red foxes annual "take" (i.e., including predation and scavenging) of mallards in the PRAIRIE POTHOLE REGION of North Dakota averaged 18.1 and 5.1% of the female and male mallard populations, respectively. More recently, Sargeant et al. (1984) estimated that in 1969-1973 fox predation accounted for 13.5% of female ducks and 4.5% of male ducks on their 3 county study area in North Dakota. It is important to note, however, that their studies were conducted during years when waterfowl and red foxes were relatively abundant. In a study conducted on Union Slough National Wildlife Refuge in northern Iowa, Fleskes and Klaas (1993) estimated each fox family took (scavenged and killed) 21.8 ducks per year (following calculations used by Sargeant et al. 1984). Densities of foxes were high (1 family/87ha) and breeding ducks were numerous during the years of the study.

Coyote

The coyote preys on both nesting female ducks and eggs (Sooter 1946, Keith 1961, Dzubin and Gollop 1972). However, they are not considered to impact breeding ducks as severely as red foxes (Johnson et al. 1989, Sovada et al. 1995). Nest success rates tend to be higher where coyotes are the principal canid compared to areas where foxes are the principal canid (Sovada et al. 1995). Results from Sovada et al. (1995) confirmed the hypothesis of Klett et al. (1988) that Adifferences in predator communities, especially the canid component, may be the reason for higher duck nest success in western portion of the PRAIRIE POTHOLE REGION of Minnesota, North Dakota, and South Dakota, where coyotes were more common than red foxes, compared to eastern portions of that regionY@.

There are several reasons coyotes are not considered to impact nesting ducks as severely as red foxes. First, coyotes are not as strongly attracted to adult ducks and eggs as a food resource. Coyotes will eat and sometimes cache eggs, however they do not have strong caching instincts and they are not compelled to cache each egg that is encountered, as are foxes (Sargeant et al. 1998). Furthermore, larger prey species that are available to coyotes are not available to the smaller red fox, and the red fox has likely evolved as a more effective predator of smaller prey, including nesting ducks. Sargeant et al. (1998) reported that when coyotes were observed encountering nests in a large enclosure, they did not show consistent and acute interest in the hen or eggs like foxes, but rather they often left nests without taking the restrained hen or eggs. When they do occasionally capture hens on their nests, they might not consume them (Sargeant et al. 1998). The remains of an adult duck killed by a coyote often resemble the remains of a duck killed by a raptor. Sargeant et al. (1998) observed captive coyotes, after they had killed a duck, pull off and discard the feathers and strip the flesh off the carcass, leaving the skeleton nearly intact.

Second, both coyote and red fox family territories are largely contiguous and non-overlapping, but coyote territories are substantially larger than those of red foxes (Sargeant et al. 1987, 1993). Therefore, the lower densities of coyote populations result in fewer predators per unit of space.

Furthermore, where coyotes live sympatrically with red foxes, the impact on nesting ducks also may be influenced by interference competition (intimidation) between the two species (see Sovada et al. 1995). Large core areas of coyote territories are void of red foxes because the foxes avoid areas where they might encounter coyotes. Foxes tend to live only on the edges between coyote territories. Hence, interspecific strife between the two species results in suppressing fox densities and limiting areas where foxes can forage.

Finally, coyotes travel only slightly farther per night than red foxes (Johnson and Sargeant 1977) and coyotes tend to hunt as pairs, whereas red foxes hunt alone, which means that fox pairs may travel over twice the total area per night of coyote pairs. Thus, red foxes would have a greater probability of encountering nests

Because coyotes pose less threat than foxes to nesting ducks, presence of coyotes can positively affect nest success of ducks. Sovada et al. (1995) suggested that a density of about 1 coyote family/25km^2 would be optimal to depress fox populations and benefit nesting ducks. However, the presence of coyotes does not necessarily result in high nest success. At Valentine National Wildlife Refuge, Nebraska, coyotes were estimated to account for 36% of nest depredations; <5% were due to other mammals (Glup and McDaniel 1988). Depredation of duck nests at Valentine Refuge was significantly lower where mammalian predators were controlled compared to areas where no mammalian predator control was conducted. After intensive control of coyotes was initiated on the refuge, the percent of nests depredated by non-coyote mammalian predators increased as did the number of these predators taken in control efforts. Control of all mammalian predators resulted in bullsnake (*Pituophis catenifer*) depredations increasing to >65% of nests, suggesting compensation. Thus, coyotes can have substantial impact on duck nests when they are abundant, yet reduced coyote abundance might not result in the desired increase in nest success.

Raccoon

The raccoon is an opportunistic omnivore, with diet reflecting seasonal and annual abundance of prey (Schoonover and Marshall 1951, Greenwood 1981). That is, foods are generally consumed in proportion to their availability. Raccoons are considered to be an important predator of ducks, especially as egg predators; they may partially or completely destroy clutches (Sargeant and Arnold 1984). They infrequently take adult ducks (Llewellyn and Webster 1960, Stoudt 1971, Cowan 1973, Greenwood 1981, Sargeant and Arnold 1984); except wood ducks (*Aix sponsa*) in cavities where they are able to kill the hens (Bellrose and Holm 1994)

Fritzell (1978) and Greenwood (1981, 1982) conducted concurrent studies of raccoons in an intensively farmed area in east central North Dakota. Birds and bird eggs occurred in 34% and 29% of 586 scats, respectively (Greenwood 1981). Large birds represented in scats were mainly Anatidae (ducks) and Rallidae (rails and coots), but also included Ardeidae (black-crowned night heron [*Nycticorax nycticorax*]). Most small birds and small eggs were Passeriformes, principally Icteridae, but included some Columbidae and Picidae. Of 64 large birds identified, 41% were waterfowl and 55% were American coots (*Fulica americana*), including some chicks. Identified waterfowl species included blue-winged teal, mallard, northern pintail, lesser scaup (*Aythya affinis*), ring-necked duck (*A. collaris*), and ruddy duck. Evidence suggests that most large adult birds were consumed as carrion (Greenwood 1981). Of large bird eggs identified, 55% were waterfowl, 40% were rails, 17% were coots, and <1% were black-crowned night herons. Consumption of birds and bird eggs increased during April-July. Consumption of birds and bird eggs was lowest during a drought year.

Total impact of raccoons on nesting waterfowl is dependent on age, sex, and experience of individual raccoons and time of season. In the North Dakota study, raccoon activity was characterized by extensive travel interspersed with periods of intensive foraging at local sites (Greenwood 1982). Adult male raccoons may encounter more nesting ducks than females or juveniles do because adult males have

larger home ranges and travel farther each night (Fritzell 1978, Greenwood 1982). Fritzell (1978) reported that adult males had high travel rates and large home ranges (mean of 25.6 km^2), compared to parous or pregnant females (8.1 km^2), and nonbreeding yearling females (6.6 km^2). Females with young <4 weeks old seldom moved >1 km from litter sites, but their range increased when young were older. For all age-sex groups, foraging habits were similar and average distance traveled each night declined from April through July.

In the PRAIRIE POTHOLE REGION, wetlands and building sites are often focal points of raccoon activities within their home range, thus duck nests in or near these features are more likely to be encountered by a raccoon (Fritzell 1978, Greenwood 1982). Fritzell (1978) reported that raccoons spend most of their foraging time in wetlands. Raccoons used buildings for litter sites and diurnal resting sites more often than for nocturnal activity. Moreover, use of building sites by all age-sex groups of raccoons decreased from April through July, as their use of wetlands gradually increased. Given these activity patterns, ducks nesting in upland areas are much less likely to be affected by raccoon predation than ducks nesting at the edge or over water, or near farmyards. However, Fritzell (1978) suggests that adult males can visit isolated stands of duck nesting habitats that are several kilometers apart and that ducks that nest in the confined but well-traveled areas a female's litter site Aprobably have little chance of escaping detection.@

Several early studies have investigated raccoons in large marshes along Lake Erie and in Horicon Marsh, Wisconsin. In the semipermanent and permanent marshes on Lake Erie, raccoons occurred at very high densities (18/km^2; Urban 1970). Many raccoons used muskrat houses for denning, which focused their activity near overwater-nesting birds. Raccoon movements were largely in emergent marsh habitat, and they spent more time in the marsh (primarily in shallow water areas) than near dikes. However, success of duck nests along dikes was near 0%, indicating that raccoons or other predators foraged along dikes. Similar to results reported by Fritzell (1978), females raising young had smaller home ranges than adult males. Urban (1970) attributed most of the duck nest losses to adult males because of their larger home range and frequency of movements. In a second study in Lake Erie's marshes, Bailey (1971) reported that raccoons destroyed 16% of 93 nests, the majority of which were along the marsh edge, where raccoons frequently traveled.

Striped Skunk

The striped skunk is recognized as a major predator of eggs in the PRAIRIE POTHOLE REGION (Sargeant and Arnold 1984, Greenwood et al. 1999), but they are not known to kill adult ducks (Sargeant and Arnold 1984, Sullivan 1990). Skunks might search specifically for bird nests, but it is more likely that skunks encounter nests incidental to their wide-range searching for insects and other foods (Wade-Smith and Verts 1982, Crabtree and Wolf 1988, Vickery et al. 1992). Because skunks are reluctant to swim, they seldom depredate nests overwater or on islands surrounded by deep water, but rather, most nest depredations by skunks occur in uplands.

Prairie skunks are opportunistic foragers. During the avian nesting season they make nearly exclusive use of animal foods, particularly invertebrates found in grasslands and wetland edges (Greenwood et al. 1999). In North Dakota, bird remains were second in occurrence in scats, following insects. Occurrence of bird remains in scats varied by season and year; birds occurred less frequently in scats in spring (33% in April-May) than in summer (51% in June-July) and occurred less frequently during a drought year (24%) than in other years (51-52%). Thick-shelled eggs, which are probably nearly all from ducks, comprised 40% of bird remains. Large birds, likely consumed as carrion, comprised 11% of bird remains. Johnson et al. (1989) found skunks to be important predators throughout the nesting season in prairie Canada, but they and Greenwood et al. (1999) suggest that skunks more commonly depredate nests later in the nesting season than earlier.

Skunks commonly forage around wetland edges, farmsteads, and along road sides (Hershey 1976;

Crabtree and Wolf 1988; Larivière and Messier 1998a,b, Greenwood et al. 1999, Phillips et al. 2000). Likewise, resting and denning sites often are around wetland edges and in farmyards (Storm 1972, Hershey 1976, Larivière and Messier 1998a). In Utah, Crabtree and Wolf (1988) found that skunks foraged primarily in densely vegetated habitats. In Manitoba, preference of skunks for heavy residual grassland cover probably was related to their intense foraging on meadow voles (Hershey 1976). These foraging habitats are the same preferred by upland-nesting ducks. Hence, skunks are likely to encounter duck nests in upland cover and along wetland edges while searching for foods. However, availability of foods does not seem to concentrate nest depredations near feeding areas, nor does it result in a detectable effect on nest success overall (Greenwood et al. 1998). Greenwood et al. (1997) found no direct evidence that provision of supplemental food affected rates of travel, distances traveled, or home range sizes of radio-marked skunks. However, lack of detectable effects during that study (conducted in 1994) might have been due to excellent habitat conditions, availability of alternative foods, and compensatory predation.

During the nesting season, skunks travel and forage as solitary individuals. Home ranges of adult females are smaller than those of males and may overlap substantially (Larivière and Messier 2000). Movements of female skunks are focused near the den site the first 2-3 weeks post-partum (R. Greenwood A. Sargeant, unpublished data); therefore, nests in that vicinity are likely to have a higher risk for depredation by foraging skunks than other nests.

American Badger

American badgers occur throughout the Prairie Pothole Region and are well adapted to living in grassland habitats, which also provides cover for nesting ducks. Overall, badgers are considered to be opportunistic foragers, consuming a variety of prey, but badgers have been largely overlooked as predators of duck eggs. However, recent studies have implicated badgers as a potentially important predator of duck eggs and eggs of other birds (Johnson et al. 1989, Roaldson 1996, Sovada et al. 1999).

Sovada et al. (1999) studied badger food habits during the duck nesting season in Minnesota (Becker, Grant, Ottertail counties) and North Dakota (McIntosh and Stutsman counties). Although their most common food items were small mammals, nearly one-third of digestive tracts of adult badgers contained bird remains (feathers or eggshells). Bird remains (found in 32% of samples) were more common in summer (61%) than spring (4%). Most bird remains were eggshell fragments from ducks (19% of all samples). It is unknown if badgers purposefully search for bird nests. Ducks, eggs and ducklings likely are not the primary food sought by badgers, but rather rodent and insects seem to be more important. Abundance and distribution of rodents and insects likely influence the impact of badger predation of ducks.

Badgers influence on local nesting populations of dabbling ducks could be substantial. Johnson et al. (1989) found a positive correlation between indices of badger activity and predation of early nests in the Canadian PRAIRIE POTHOLE REGION, suggesting badgers may be an important predator of early-nesting ducks. Nests of dabbling ducks in grassland habitats are more vulnerable to badger predation than nests along wetland edges or overwater because badgers are most active in upland habitats (Messick and Hornocker 1981). Badgers seldom depredate overwater nests (Sargeant and Arnold 1984, Brandt 1994). Vulnerability of upland-nesting ducks to badgers might be higher where loss of grassland habitat has concentrated nests and badger foraging activity in remaining fragmented grassland areas (Klett et al. 1988).

American Mink

The American mink favors areas that include numerous permanent wetlands and streams, thus, western Minnesota and other parts of the Prairie Pothole Region are ideal for sustaining healthy mink

populations. Minks forage in or near permanent and semipermanent wetlands and spend little time foraging in the uplands (Sargeant and Arnold 1984, Eagle 1089, Arnold and Fritzell 1990). Hence, female ducks that nest overwater or on small islands are especially vulnerable to mink predation (Eberhardt 1973, Sargeant and Arnold 1984, Aufforth et al. 1990). Minks also are considered to be a major source of mortality for prefledged ducklings in areas with semipermanent or permanent wetlands (Talent et al. 1983, Korschgen et al. 1996, Pietz et al. 2003; G. L. Krapu, USGS, Northern Prairie Wildlife Research Center, unpublished data).

 In North Dakota, waterfowl (including American coots and grebes [*Podiceps sp.*]) accounted for 86% of the avian prey consumed by minks (Eberhardt and Sargeant 1977). Coots were the predominant prey item (70% of waterfowl remains) and ducks comprised 11% of the waterfowl total. In southern Manitoba, waterfowl (eggs, ducklings, and adults) comprised 23% of the total diet of male minks during AprilBJuly (Arnold and Fritzell 1987). Minks shifted from a diet composed largely of mammals in April toward an increasingly avian diet in May, coinciding with nesting and likely reflecting a shift in relative food abundance. Most egg remains were found in scats collected in June. Peak predation on adult ducks and ducklings occurred in July.

Birds more closely associated with semipermanent and permanent wetlands are more vulnerable to mink predation. In south-central North Dakota, minks killed more female (78%) than male diving ducks, but more male than female (33%) dabbling ducks (Eberhardt and Sargeant 1977). Remains of northern pintails, a species that nests early and prefers sparse upland habitat for nesting, were consumed less than expected relative to their composition in the nesting population. In contrast, remains of ruddy ducks (*Oxyura jamaicensis*), a late-nesting species that prefers to nest overwater, were found more than expected. In southern Manitoba, however, where the most suitable nesting cover for dabbling ducks was along wetland edges, remains of dabbling ducks and their eggs were frequently found at mink dens (Arnold and Fritzell 1989).

Nesting ducks on islands also are vulnerable to mink predation. Aufforth et al. (1990) reported that 48% of all nest failures on islands at J. Clark Salyer Refuge in North Dakota were attributed to mink and 91% of failures that could be assigned to predation were destroyed by minks.

Male minks in prairie have relatively large home ranges (average of 6.5 km^2 during May-July) compared to minks in other regions (Arnold and Fritzell 1987). Information on home ranges of female minks are lacking, but their areas of activity are likely smaller than those of males and, like other mammalian predators, females with young focused their foraging activity around denning sites during the period when they are raising young. Birds nesting or foraging in areas near mink dens are likely to be more vulnerable to mink predation.

In North Dakota, Talent et al. (1983) found minks to be a major source of mortality of mallard ducklings and Pietz et al. (2003) attributed ∃66% of the depredation of gadwall (*Anas strepera*) ducklings to minks. Minks accounted for 62% of depredations of mallard ducklings in a study of radio-marked hens and ducklings in central North Dakota (G. Krapu, USGS, Northern Prairie Wildlife Research Center, unpublished data). Minks were also serious predators of ducklings at Agassiz National Wildlife Refuge in north western Minnesota, an ecotone of prairie and northern forest ecosystems dominated by semipermanent to permanent wetland impoundments. There, minks were the single greatest cause of mortality (39B100% of all deaths) each year for canvasback (*Aythya valisineria*) ducklings from hatch to 4 weeks of age (Korschgen et al. 1996).

Abundance and distribution of minks, and in turn their impact on waterfowl populations, are influenced by water conditions. Eberhardt and Sargeant (1977) noted very little predation by minks on waterfowl in 1973, a drought year when waterfowl abundance was low. Krapu et al. (2000) found mallard broods had a higher survival rate when seasonal ponds were abundant, although minks were still the most frequent cause of mortality. Those authors hypothesized that mallard ducklings in seasonal ponds are less vulnerable to aquatic predators, such as the mink, that prefer permanent water. The

hypothesis was based on research of mink in the PRAIRIE POTHOLE REGION, which indicated that minks avoid temporary and seasonal ponds and dry basins (Arnold and Fritzell 1990), reproduce poorly during drought (Eberhardt 1974), and rely on permanent water to survive severe drought (Sargeant et al. 1993). As a result, in landscapes lacking permanent water, mink populations are likely to take several years to recover and become a major cause of duckling mortality following a severe drought (Krapu et al. 2000). Krapu et al. (2000) reported exceptionally high brood survival in the wet years following a severe drought. The daily risk of death experience by gadwall ducklings was twice as high when seasonal wetlands were scarce (i.e., broods more concentrated on semipermanent and permanent wetlands) than when they were abundant (Pietz et al. 2003).

The impact of minks on the local duck population also is influenced by the abundance of ducks and the availability of alternative prey. In North Dakota on a single wetland, one mink family consumed 8% of the 36 adult coots and 52% of 144 young coots but apparently took no adult ducks and only 11 juvenile ducks (Eberhardt and Sargeant 1977). Because of movements by broods on and off the wetland, the proportion of ducklings consumed by the ducks could not be determined. The authors suspected high vulnerability of young coots was related to vocalization among hatched coots and lack of attention to chicks by adult coots. In Manitoba, Arnold and Fritzell (1987) estimated that each male mink consumed an average of 2.75 kg of adult ducks, 1.5 kg of ducklings, and 0.9 kg of duck eggs during a single waterfowl-nesting season. This is equivalent to 3 adults, 15 week-old ducklings, and 18 eggs for mallards, or 7 adults, 25 ducklings, and 30 eggs for the smaller blue-winged teal. In context, however, this would be about 1% of the local waterfowl population and its potential reproductive output. Fleskes and Klaas (1993) also estimated that minks killed approximately 1% of female dabbling ducks in northern Iowa. Because juvenile minks forage within their maternal home range (Eagle 1989), the effective density of minks in a home range of a breeding female may increase from 1 to 8 in July-August. However, their foraging effort would be concentrated around their rearing dens (Eberhardt and Sargeant 1977).

Long-tailed and Short-tailed Weasels

Surprising little is known about the ecology of weasels in North America, despite the fact that weasels are known to have substantial impact on populations of their main prey (King 1983). Weasels focus primarily on small mammal prey but, their diet varies seasonally in response to temporal shifts in prey abundance (Sheffield and Thomas 1997), thus weasel predation on waterfowl probably is influenced by annual and seasonal availability of small mammals.

There are three species of weasels in the Prairie Pothole Region: long-tailed weasel (*Mustela frenata*), short-tailed weasel or ermine (*M. erminea*), and least weasel (*M. nivalis*). Both long-tailed weasels and short-tailed weasels are known predators of duck eggs, ducklings, and adult ducks (Teer 1964, Crabtree and Wolf 1988, Fleskes 1988). It is unknown if the least weasel has any impact on ducks.

Long-tailed weasels and short-tailed weasels are not considered to be significant predators of adult ducks. Keith (1961) reported that hens were occasionally killed at nests by long-tailed weasels; Fleskes (1988) did not find the same for the smaller short-tailed weasel. In areas where weasels are relatively common, they can have significant impact on the survival of duck eggs. In Manitoba, of 59 nests with known histories, 23 were destroyed by predators, 3 of which were attributed to predation by long-tailed weasels (Teer 1964). In northern Iowa, of 263 upland duck nests that failed due to predation, 38 (14%) had eggs taken by weasels; 27 of the 38 nests failed solely due to weasel predation (Fleskes 1988). Destruction of nests by weasels typically involves gradual removal of eggs from individual nests during a period of several days (Fleskes 1988).

In agricultural areas, long-tailed weasels are typically associated with waterways not suitable for cultivation and their activity seems partially restricted to the vicinity of freestanding water (Fagerstone

1999).   Nests located in such areas are most likely to be encountered by long-tailed weasels, but both species of weasels typically forage in upland habitats in pursuit of small mammals.

Franklin's Ground Squirrel

The Franklin's ground squirrel (*Spermophilus franklinii*), the only rodent believed to affect duck production in the Prairie Pothole Region, is one of the least-studied predators of duck eggs and ducklings in the Region (Sowls 1948, Greenwood 1986, Sargeant et al. 1987). Distribution is typically Αdiscontinuous and sparse@ (Murie 1973), but populations can be locally abundant. Therefore, the Franklin's ground squirrel is only considered an important predator of duck eggs locally (Sowls 1948, 1955; Greenwood 1986; Sargeant et al. 1987).

The Franklin's ground squirrel is the most omnivorous of the ground squirrel species that inhabit the PRAIRIE POTHOLE REGION. The impact of this species on ducks is primarily as an egg predator, although they may take ducklings (Sowls 1948, 1955, Sargeant et al. 1987). Unlike larger predators, destruction of an entire clutch by ground squirrels probably is uncommon. Rather, they more typically take some eggs out of individual nests resulting in reduced clutch size (Sargeant et al. 1987). Sowls (1948) attributed mortality of some ducklings found along roads to Franklin's ground squirrels, although he did not directly observe a predation event; he also found duckling remains at burrows of ground squirrels. He suspected ground squirrels might take individual ducklings that had become separated from a brood.

Sowls (1948) attributed 12% of 95 depredated nests to Franklin's ground squirrels. Based on his field data and review of other duck nesting studies from many areas in the central United States, he concluded that Franklin's ground squirrels are a localized problem, Αcausing serious losses only during certain times and certain places. Marshy areas with wooded borders provide most ideal situations for ground squirrel predation upon duck nests.@

Franklin's ground squirrels prefer dense or brushy habitats (Choromanski-Norris et al. 1989), thus grasslands managed for waterfowl production are well suited to this species. Patterns of habitat use by Franklin's ground squirrels in central North Dakota could not be explained by vegetation height and density or by litter depth (Choromanski-Norris et al. 1989). These authors hypothesized that northern pocket gopher (*Thomomys talpoides*) burrow systems had a major, but indirect effect on habitat use, because ground squirrels used abandoned burrow systems.

Franklin's ground squirrels tend to be secretive and they can easily go undetected without trapping to verify their presence. Their vocalization is similar to that of the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), but slightly deeper in tone. Experienced observers can distinguish between the calls, and vocalizations in the spring can be an indicator of presence.

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PART III:
ASSESSMENT OF MANAGEMENT ACTIVITIES (IDENTIFIED BY MANAGERS FOR THIS EXERCISE)
CURRENTLY APPLIED BY REFUGE AND WETLAND DISTRICT MANAGERS
IN PRAIRIE POTHOLE GRASSLAND HABITATS
Marsha A. Sovada, Molly J. Burns, and Jane E. Austin

Introduction

Increased duck production is the primary goal of the United States Fish and Wildlife Service on most National Wildlife Refuges and Waterfowl Production Areas in the Prairie Pothole Region. To attain this goal, it is essential to attract breeding ducks to specific areas and capitalize on their inherently high production potential. We recognize the importance of the relationship between habitat and the welfare of breeding birds, which includes security from predation. Conservation and restoration of essential habitats are fundamental approaches to maintaining sustainable populations. Despite habitat management, however, attempts to increase nest success often fail (Clark and Nudds 1991). Contributing to this failure seems to be that habitat management sometimes has been approached at too small a scale. Factors influencing the chance of an individual nest hatching are related not only to the cover at the nest site, but also to the grassland component of the surrounding landscape (Greenwood et al 1995, Reynolds et al. 2001). Nest success is positively correlated with the amount of grassland in the landscape. On a large scale, land acquisition and cropland retirement programs (e.g., Conservation Reserve Program) can be used to compose favorable landscapes.

Because many management units exist as small, isolated tracts, managers often must consider small scale management as well as the large scale approach. At the small scale, severe depredation problems exist in many locations and seriously compromise achievement of Service goals for managed properties. Clearly, effort must be directed toward predation management that can be effectively integrated with a habitat management program. To approach predation management locally, biologists need to consider several factors. First, knowledge of the predator species that comprise the predator community can guide the direction of predation management (see Part II and Appendix). Second, managers must evaluate the cost effectiveness of management and the tradeoffs (discussed below). Management techniques for reducing the impact of one predator species might benefit another predator species. Ultimately predation management becomes a ʺbalancing actʺ to find the best combination of tools. Third, managers must consider the scale at which they are able to apply management. For example, if block size is the focus, application should be at the landscape level, which probably precludes some intensive management techniques. However, if a small area is being managed, then viable management applications will probably include intensive management methods (e.g., electric fences, barriers). Finally, because management techniques and approaches are not universally applicable, managers must assess if the management tools are appropriate for the landscape being addressed. A technique that works in one area may be ineffective in another.

The Fish and Wildlife Service Region 3 managers identified several topics that they wanted to be addressed in the context of nest depredation and predators within this document. In the following sections, we discuss a range of management tools identified by the managers, the assumptions associated with these tools, and their efficacy.

Tree Removal

Should trees/shrubs be removed from managed areas?

Encroachment by trees and shrubs in grassland nesting habitat is commonly thought to have negative consequences to breeding ducks and other grassland nesting birds. Trees and shrubs provide nesting habitat for American crows (*Corvus brachyrhyncos*) and black-billed magpies (*Pica pica*), 2 species known as predators of waterfowl eggs and occasionally on ducklings (Kalmbach 1937, Linsdale 1937, Sowls 1955, Sutherland 1982, Sugden and Beyersbergen 1987, Sullivan 1990, Sargeant et al. 1993). Crows and magpies benefit greatly from trees in shelterbelts and farmsteads that provide nesting areas and food (Schorger 1941, Sargeant et al. 1993).

Trees also provide nesting habitats for several raptors, including red-tailed hawks (*Buteo jamaicensis*), Swainson's hawks (*B. swainsoni*), and great-horned owls (*Bubo virginianus*). Diets of these species consist primarily of small mammals, but include adult ducks and ducklings (Murphy 1993, Korschgen et al. 1996). Waterfowl prey can be locally important for raptors. For example, Murphy (1997) reported ducks were the most important prey category for nesting great-horned owls in northwestern North Dakota.

Shelterbelts and other types of linear tree plantings are used as travel corridors by mammalian predators, such raccoons (*Procyon lotor*), thus grassland habitat containing or adjacent to trees might have predator movements directed to the grassland. Furthermore, raccoons and other predators might benefit from the shelter and escape refuge provided by the increased number of trees in the prairies.

In contrast to the negative aspects of trees and shrubs to nesting ducks, the benefits of short brushy habitat, such as western snowberry (*Symphoricarpos occidentalis*) has been well documented (e.g., Keith 1961, Salyer 1962, Smith 1971, Stoudt 1971, Cowardin et al. 1985, Duebbert et al. 1986, Sugden and Beyersbergen 1987, Greenwood et al. 1995). Smith (1971) suggested that brush was especially attractive to nesting ducks in dry years, when grass was in poorer condition than in wet years. Greenwood et al. (1995), in an extensive study of nesting waterfowl in the PPR of Canada, found mallards (*Anas platyrhynchos*) and gadwalls (*A. strepera*) most preferred brushy habitat for nesting, and blue wing-teal (*A. discors*) preferred brush second only to road-right-of-ways. Cowardin et al. (1985) found similar results for radiomarked mallards in North Dakota.

In summary, trees and shrubs are not beneficial to nesting ducks and removal could have benefits. Shrubs (untilled land ≥ 0.2 ha dominated by woody vegetation ≤ 1 m tall in grass, definition from Greenwood et al. 1995) attracts nesting ducks (especially mallards) and can be particularly important habitat in drought conditions (Smith 1971Greenwood et al. 1995).

Rock Pile and Building Removal

Are rock piles and buildings beneficial to predator species? Should they be removed from areas of upland nesting habitat?

Raccoons commonly use farmstead buildings as den sites or day-time resting retreats; both occupied and unoccupied farm sites are used. A telemetry study of raccoons in a North Dakota conducted during the duck-nesting season reported 44% of diurnal locations and 28% of nocturnal locations at building sites (Fritzell 1978). Fritzell (1978) also found there was a decline in the use of buildings and an increase in use of wetlands as the spring progressed into summer. Notably, Fritzell's study showed that raccoons seldom used "upland" (e.g., grassland fields), thus nests near buildings and wetlands are most vulnerable to predation by raccoons (Fritzell 1978).

Buildings also provide winter shelter for raccoons and farm sites provide ready food sources of grain, seeds, and rodents during the season when natural foods are not as available. This shelter and food source might facilitate winter survival, especially in the prairies where other types of shelter (e.g., hollow trees, stumps, abandoned beaver lodges) are less abundant.

Natal and winter dens, and resting areas of striped skunks (*Mephitis mephitis*) are sometimes located under buildings in occupied or abandoned farmsteads and under rock piles (Larivière et al. 1999). There is an assumption that if abandoned buildings and rock piles are removed that there will be a significant reduction in den sites for skunks. However, skunks are versatile in selection of denning sites. Very often dens are underground holes made by other animals (e.g., badgers [*Taxidea taxus*], muskrats [*Ondatra zibethicus*]) and they have the ability to dig their own dens (Wade-Smith and Verts 1982). Thus, it is unlikely that skunks would be limited by available den locations. Furthermore, daytime resting sites are most often at above-ground locations (Wade-Smith and Verts 1982).

Female skunk activity during rearing of young will be focused near the den site. Females that are caring for young might not leave their den for several days following parturition, thereafter travel may be restricted to near the den (Larivière and Messier 1998, Greenwood et al. 1999). Within the restricted range of movement, food resources are potentially more vulnerable because concentrated movements results in higher probability of encounters. Therefore, den sites that are near or in grassland areas managed for duck nesting could focus skunk activity in that area. Removal of such potential dens sites could be beneficial to nesting ducks, but there is no guarantee of any influence on nest success.

In summary, abandoned buildings and rock pile have no benefit to nesting ducks, but removal does not guarantee improved nest success for ducks. Buildings and rock piles often are a focal point for raccoon and skunk activity, and removing these features that attracts predators has potential for benefiting ducks that nest in the vicinity. It is unlikely that removal will influence density of predator species. Managers must weigh the costs of removing buildings or rock piles against the potential benefit to nesting ducks that nest in the area of that feature.

Block Size of Grasslands, Edge Effects, and Landscape Composition

What do we know about the influence of grassland fragmentation (block size, edge effects and landscape composition) on predation rates?

Many of the important predators, such as red foxes, coyotes, skunks, and badgers, function at a scale different from their prey. These predators have large home ranges and will readily cross large areas, such as cropped fields, that fragment grassland habitat to forage in the grassland patches. These cropped fields don't represent barriers to the predators and thus don't fragment the population or the predator community. But, patch size and shape may strongly interact with patch distribution to influence predation rates. For example, small patches may be completely searched for prey, whereas larger patches may have a core area in the center where predators do not search or are less efficient. Research is beginning to reveal influences of grassland block size, edge effects and landscape composition on predation rates. The following summarizes what we understand about the influence of grassland fragmentation on duck nest predation.

Block size

The loss and fragmentation of grassland on the breeding grounds, which resulted in smaller patches of suitable nesting habitat surrounded by unsuitable habitat, are factors affecting a variety of grassland nesting birds by influencing habitat selection, distribution, and especially reproductive success (Cowardin et al. 1983). There is an assumption that nest success is higher in larger blocks of grassland because (1) there is more prey available, including more ducks which buffer predation on individual ducks; (2) nests are more dispersed, which reduces probability that predators will encounter individual nests (i.e., reduced foraging efficiency); (3) increased spatial heterogeneity enables ducks to select better concealed sites; and (4) there often is a different predator community present that is more favorable for nesting ducks. This assumption is likely correct; however, the magnitude of the benefit of having large grassland blocks available for nesting ducks is not completely understood. Sovada (1993) and Reynolds et al. (2001) speculated that on a large scale, that is landscape level rather than patch size level, the

assumption above is a likely explanation for the typically improved success of nests that followed the implementation of the Conservation Reserve Program (CRP) in large tracts planted grasses and forbs (CRP fields).

Studies have addressed the relationship between field size and nest success, but results from these studies are not consistent. Some studies found greater nest success in large patches compared to smaller patches or strip habitats (Klett et al. 1988, Kantrud 1993, Greenwood et al. 1995), whereas others have found no relationship between nest success and patch size (reanalysis of Duebbert and Lokemoen [1976] by Clark and Nudds 1991, Clark et al. 1991, Pasitschniak-Arts and Messier 1996) or little evidence of a patch size effect after other variables were considered (Sovada et al. 2000). Horn et al. (In press) found a curvilinear relationship between nest success and field size (2-606 ha), with higher success in very small and large fields and lower success in medium-sized fields.

There may be several explanations for the variability in the relationship between field size and nest success as reported from different studies. These studies were conducted in different years and in different areas of the PPR, thus confounding the effects of variability in water conditions, weather, predator community, alternative prey populations, duck populations, and nest densities. Furthermore, the scale of the investigation influences results. For example, there has been a wide range of definitions for grassland patch size; the largest grassland field in Greenwood et al. (1995) was 9,200 ha, compared to the range of large patches sized (106-2,342 ha) in the study by Sovada et al. (2000). Also, the composition of habitats surrounding the sites being studied can influence nest success. For example in large study of nesting ducks, Greenwood et al. (1987, 1995) reported nest success was positively correlated with the amount of pasture available on the study area. Finally, the composition and density of the predator community influences the results of nesting studies and contributes to variable results.

Phillips et al. (2003) evaluated the effects of fragmentation from the Apredator's perspective.@ One objective of the study was to determine whether landscape features influence how predators use and move through habitats; ultimately influencing predator impact on nest success of ducks. They examined movements of red foxes *(Vulpes vulpes)* and striped skunks, and duck nest success in two contrasting landscapes. One landscape had low (15-20%) grassland composition and the other had high (45-55%) grassland composition. In the low grassland landscape, foxes were attracted to the isolated patches of planted cover and they more frequently explored the complete interior of other grassland areas. In high grassland landscapes foxes were rarely located in the interior areas of grassland fields; but notably, at data from one study site suggested that wetlands located well into the interior of large grassland seemed to attract foxes into the grassland's inner area. However, sample size was small and more research is needed to understand these relationships.

Edge

A consequence of habitat fragmentation is that small patches have greater edge-to-area ratios than large patches of the same shape. Ducks nesting close to edges may be more susceptible to nest predation by mammalian predators (Pasitschniak-Arts and Messier 1995, 1996). Proposed reasons for increased mammalian predation close to edges include higher concentration of prey along edges presumably leading to increased foraging opportunities (Gates and Gysel 1978, Chasko and Gates 1982, Dijak and Thompson 2000), and predators using habitat edges such as roads as travel corridors (Bider 1968, Small and Hunter 1988) and taking prey incidentally (Vickery et al. 1992).

However, results of studies examining the relationships between distance to grassland edges and nest success have also been inconsistent. By monitoring artificial duck nests place in large fields (200 ha), Pasitschniak-Arts and Messier (1996) found a positive relationship between nest survival and distance to nearest field edge up to a distance of 250 m, but then nest success declined. In small fields (50 ha), edge effect was detected. However, a natural-nest study by Pasitschniak-Arts et al. (1998) found little evidence that nest survival was influenced by distance to different edge types. A reason for the conflicting results between these studies might be the use of artificial and natural nests (Butler and Rotella 1998). Horn et al. (In press) similarly found no evidence of an edge effect on nest success in planted

cover (i.e., CRP lands). The lack of a strong edge effect, contrary to what has been reported in forest-field ecosystems, might be related to vegetation structure around edges in prairies being similar to core areas and surrounding habitats (e. g., wheat) during the growing season.

Edges around wetlands influence predator movement (see Phillips et al. 2003). Wetland edges and wet meadows contain many invertebrate and vertebrate food resources attractive to striped skunks, red foxes, and other predator species (Greenwood et al. 1999). Striped skunks strongly selected for wetland edges in both agricultural and grassland dominated landscapes (Phillips et al. 2003). Because of the attraction to wetland edges, nests located near those edges are more likely to be encountered by a predator.

Composition of perennial grassland in the landscape

Many predators in the northern Great Plains are generalists and it seems that habitat fragmentation does not strongly influence their populations. Predators such as red fox and striped skunk are wide-ranging and move among patches of perennial grassland. Populations of these predators are not generally limited by food and their population densities may be little affected by fragmentation and loss of grassland habitats, except perhaps, under conditions of extreme loss. Loss of nesting habitats without a significant reduction of predator density likely results in predators' intensive use of the remaining grassland habitat. Consequently, nest will be more vulnerable as chance of predators encountering nests increases because predators are spending more time in the remaining habitats suitable for nesting ducks.

In the PPR, ducks occupy breeding habitats based on availability of wetlands in spring (Johnson and Grier 1988), thus in areas where wetlands and croplands are abundant, ducks are at great risk to predation because they will nest in the scant patches of nesting cover that remain in those landscapes. There is a positive relationship between acres of cropland and the rate of nest predation. For example, Greenwood et al. (1995) reported that nest success in the Prairie Region of Canada decreased about 4 percentage points for every 10 percentage point increase in availability of cropland.

The amount of grassland in the landscape can influence the composition of the predator community, which in turn can affect predation rates. For example, coyotes and badgers are often associated with large grassland areas (Messick et al. 1981, Sargeant et al. 1993) where they are able to avoid human activity. In contrast, some predator populations likely benefit from stable food sources (waste grain) consequential to agricultural presence on the landscape. Furthermore, predator communities can vary from year to year and vary greatly across the prairies (Johnson et al. 1989, Sargeant et al. 1993).

It is not clearly understood how variation in the predator community influences nest success. However, studies have shown that the canid component of predator communities can influence success of nests (Johnson et al. 1989, Greenwood et al. 1995, Sovada et al. 1995); red foxes are more detrimental than coyotes to nesting ducks. If perennial habitat loss resulting from agricultural activities, affects composition of predator communities, this mechanism might influence variation in nest success. Evidence further suggests that nest success would be enhanced by large tracts of perennial habitat or in landscapes that have a higher proportion of perennial habitat.

In summary, there is no clear answer how fragmentation of grasslands affect nesting ducks, although findings indicate that there is a positive relationship between patch size and nest success. We concur with Clark and Nudds (1991) however, that it may be impractical to conduct the experiment needed to overcome inherent environmental variation and convincingly test this hypothesis. The most appropriate size, configuration, and location of grassland tracts to be of greatest benefit to duck populations likely will continue to be the subject of conjecture. We believe it is sufficiently clear however, that small isolated tracts of nesting habitat are of marginal benefit to nesting ducks, unless concerted efforts are made to manage these tracts to reduce predator effects. Small isolated tracts of grassland tend to be visited extensively by numerous predators of nesting ducks, especially red foxes (Sovada et al. 2000). Restoration of small isolated tracts of grassland habitat without accompanying predator management might have negative effect on duck populations, because female ducks will be attracted to these grassland areas for nesting and they likely will be exposed to high levels of predation.

Ideally, landscapes with sufficient wetlands and ample grassland configured in relatively large tracts are the most productive areas for nesting ducks. Thus, in summary, evidence suggests that increasing habitat patch size, reducing patch isolation, and increasing the density of habitat patches or creating landscapes with high proportion of grassland are management actions that would likely benefit nesting ducks.

Composition and Heterogeneity of Grasslands

Does composition and heterogeneity of grasslands influence predation rates and predator movements?

Management practices emphasize relatively tall and dense cover on wildlife management areas (Gilbert et al. 1996) and on lands enrolled in the Conservation Reserve Program (Johnson and Igl 1995). This emphasis is appropriate in western Minnesota because such cover is rare on private lands where crop production and intensive grazing are dominant land uses. Results of many studies demonstrate that tall dense cover can be highly attractive and productive for numerous grassland bird species (Cowardin et al. 1985, Johnson and Igl 1995, Dale et al. 1997).

We do not have an understanding of how predation rates might be influenced by heterogeneity of nesting habitats. Ducks are attracted to dense nesting cover, and heterogeneity within nesting habitat might influence nest site selection within grassland fields. In a study by Greenwood et al. (1995), mallards selected brushy areas for nesting above other habitat classes (grass, cropland, wetland, hayland, woodland, right-of-way, odd area), followed by right-of-way. Brush habitat most often was western snowberry (*Symphoricarpos occidentalis*) found in pastures of native grass. Gadwalls also selected for brush, followed by odd areas. Odd areas were defined as grass and forbs <2 ha and an array of other features usually found in cropland (e.g., rock piles, gravel borrow pits, barrow borders of upland vegetation around wetland and along fences between areas of cropland). Blue-winged teals preferred to nest in right-of-ways followed closely by brush. Preferences for nesting habitat by northern pintails were similar to those of mallards, except that cropland was ranked third. These selections by the ducks suggest that a brush habitat might be a valuable component of pastures attractive to nesting ducks. Greenwood et al. (1995) reported that nest success for ducks in brush was 19%, second highest to nest success in woodland (25%). Use of native grassland by nesting ducks and the importance of brush have been reported in other studies (e.g., Keith, 1961, Salyer 1962, Smith 1971, Stoudt 1971, Cowardin et al. 1985, Duebbert et al. 1986, Sugden and Beyersbergen 1987). There is no available information about the relative attractiveness of brushy areas in context of seeded grassland.

Although brush seems to be selected by mallards, at least in pastures, these brushy areas also serve as habitat for many alternative prey species (Greenwood et al. 1999) and, therefore, likely attract predators. For example, Greenwood et al. (1999) identified sites where striped skunks foraged for scarab beetle larvae, a favorite food of skunks. Scarab larvae were often concentrated in patches of western snowberry and low areas in pastures, where snow is trapped in winter, providing moist soil in spring and excellent habitat for scarab larvae. Skunks are attracted to these focal areas of high invertebrate density, returning persistently to forage nightly. Nests located in these focal areas are more likely to be detected and destroyed by skunks or other predators attracted to the site.

It is important to understand that there is constant "give and take" when trying to understand predation risk related to Amicrohabitats@ or alternative prey. Alternative prey can confound management because they can attract predators to an area, making the nests in the area vulnerable; and conversely they can buffer the effects of predation. It is a balance that is difficult to identify and not well understood. Clearly more research is needed to understand the role of nest site selection and alternative prey in management of nesting birds. This research direction could include a component to examine how habitat heterogeneity affects abundance and distribution of alternative prey species.

Restored Wetlands

What do we know about predator use of restored wetlands and what should be considered regarding predators in wetland restoration?

The North American Waterfowl Management Plan mandated the restoration of many wetlands to increase the production of waterfowl and other migratory birds (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1986). Wetland ecosystems are clearly important to breeding ducks and many studies have evaluated the use of natural and restored wetlands by breeding birds. Research generally has found that restored and natural wetlands attract similar numbers of breeding waterfowl (Ratti et al. 2001; but not necessarily nonwaterfowl species, see Schreiber 1994, Schuster 1998) and that invertebrate biomass in recently restored wetlands is generally adequate to meet nutritional demands of breeding waterfowl (Delphey 1991). No information is available about predator use of restored wetlands; however, there is no reason to believe that predators would use restored wetlands less intensively than natural wetlands. The invertebrate and vertebrate food resources are available, which will attract predators, especially mink (*Mustela vison*), skunk, and fox.

An urgent need is to determine what aspects of the landscapes features should be considered in designing restoration to reduce predation impacts. For example, there is limited evidence that wetlands in large grasslands are features that draw predators into the core areas of the grassland (M. Phillips, USGS, Northern Prairie Wildlife Research Center, unpublished data). This could mean that restoration of wetlands well in the interior of grassland could draw predators into grassland areas (i.e., nesting habitats) that they might not otherwise visit. However, we do not have definitive data to support this supposition.

In summary, the value of wetlands to nesting waterfowl is clear, but also, these wetlands attract many predator species largely because of the invertebrate and small mammal food resources found at the wetland edge. Unfortunately, we don't know enough about how predators are using the landscape to provided sound advice on what to consider when restoring wetlands to mitigate impacts of predation.

Predator Exclosures and Water Barriers

Are predator barriers effective management tools, and what should be considered in barrier design and application?

The use of predator exclosure fences is an important management option because of the potential for protecting small areas to increase recruitment in the larger surrounding area (Cowardin et al. 1998). Higher nest success (Lokemoen et al. 1982, LaGrange et al. 1995), higher nest densities (Cowardin et al. 1998), and an increased proportion of the breeding population (Cowardin et al. 1998) have been documented inside predator exclosures compared to surrounding areas outside of exclosures. Nest success on Waterfowl Production Areas within predator exclosures was 65% (ND) and 55% (MN) versus 45% and 12% in control areas over 3 years (Lokemoen et al. 1982). During a period of increasing drought from 1987 to 1991, Cowardin et al. (1998) monitored populations of dabbling ducks on 9 51-km^2 study areas, 3 of which contained a centrally located 25-ha predator exclosure and three of which served as control areas. Nest densities inside exclosures averaged 1.2 nests/ha, and nest success averaged 72% over 5 years, substantially higher than in similar habitat outside exclosures (Cowardin et al. 1998).

Important considerations in a decision to erect a predator exclosure are cost constraints and suitable locations. Lokemoen (1984) found electric fences around grass-legume cover to be among the most cost-effective management practices in terms of cost/fledged young in the pothole region of the Dakotas and western Minnesota. With an increase in fence length, area enclosed increases faster than the perimeter. Therefore, constructing the largest possible exclosure can maximize cost efficiency. However, increasing the length of fences also increases the likelihood of a breach.

There are a variety of fence designs (Rondeau and Piehl 1989, Greenwood et al. 1990, Howerter et al. 1996). Mesh extending >150 cm above ground is recommended to better exclude mammalian (especially canid) predators (Howerter et al. 1996); however, use of this safeguard necessitates the

installation of exits (see below; ducklings can pass through the mesh, but hens cannot and may not fly over the fence and call their brood through). Several hen exit designs have been tested that worked well (Pietz and Krapu 1994, Howerter et al.1996, Meeks 2001).

Predator control inside the exclosure is essential. Intensive predator removal should begin after the fence is energized in the spring (about 2 weeks prior to the start of waterfowl nesting season), and some form of predator control should continue throughout the nesting season. Regular checks of the fence during the nesting season are necessary to make sure that the fence is functioning properly (structure is intact, wires are energized, voltage is adequate, etc.) and that large predators have not gained access. Howerter et al. (1996) reported that, despite the work of 2 trappers, at least 1 large mammalian predator species was resident in or gained access to every predator exclosure in the study (6 16.2-ha exclosures monitored for 2 years). Increased, targeted predator control may be necessary if predation by smaller mammalian predators (e.g., weasel, ground squirrel, mink) that fences are not designed to exclude take a heavy toll on nests or if avian predation becomes a problem. LaGrange et al. (1995) studied the effects of a 21-ha predator exclosure in north-central Iowa. They found that although nest success was higher in the fenced area than outside of it, it was still only 32% inside the fence over the 8 years of the study; short-tailed weasels and avian predators accounted for most of the predation within the exclosure. Howerter et al. (1996) noted that if predator exclosures are to produce the desired results, a commitment of staff time is required to maintain the fences and ensure that they are predator free. They recommended that exclosures be placed where adequate maintenance is possible. One important consideration is to not enclose wetlands or low wet areas within the fence. Wetlands attract minks and the low areas are used as travel corridors by minks.

The effectiveness of exclosures for increasing nest success is highly dependent on location. Predator fences should be built in areas with moderate to high pair densities and where mammalian depredation of nests is significant. Also appropriate, are sites near large wetland complexes that are rarely affected by drought and with limited upland nest sites. The fence should enclose an area of quality upland nesting habitat that is free of wetlands, rock piles, trees and other features that may attract predators into exclosures. In addition to increasing the risk of predation, an enclosed wetland may not be acceptable brooding habitat, as evidenced by hens with broods attempting to exit exclosures containing wetlands (Howerter et al. 1996). Low drainage areas are used by minks as travel corridors and thus should be avoided. Fence posts can be modified to prevent perching by raptors and crows. Site selection should also consider topography, as fence maintenance problems are most often associated with rough or wet ground.

Increases in nest success may be offset if initial brood movements to wetlands are impeded, leading to increased duckling predation or abandonment. Exclosures have been shown to delay the movements of the adult females with broods (Greenwood et al. 1990, Pietz and Krapu 1994, Trottier et al. 1994, Howerter et al. 1996, Schultz 1997). Some biologists and managers have suggested that brood delay may be related to the height of fences, but Sargeant et al. (1974) suggested that females were reluctant to fly over even relatively short (0.6m) mesh fences (and see Pietz and Krapu 1994). Therefore, it is recommended that exclosures with mesh fencing to the ground should have ground-level exits for females with broods (Pietz and Krapu 1994, Trottier et al. 1994, Howerter et al. 1996). At a minimum, exits should be placed in corners and adjacent to nearby wetlands. Pietz and Krapu (1994) also suggest that a strip of vegetation along the fence be removed as a travel corridor and to facilitate easy location of exits by hens, but Howerter et al. (1996) suggest that this exposed area may increase brood vulnerability to avian predation. No increases in the presence of predators have been reported in exclosures with exits versus exclosures without exits.

Howerter et al. (1996) estimated travel time and duckling survival for 32 broods hatched within intact 16.2-ha exclosures, 31 broods hatched in exclosures modified with exits, and 23 control broods in the parkland of southeastern Saskatchewan. Mayfield nest success estimates did not differ between intact and modified exclosures, but hens with broods spent an average of 23.7 hours trying to exit intact exclosures and only 3.2 hours trying to exit modified exclosures. Less than 38% of radiomarked

ducklings from intact exclosures survived the trip to their initial wetland compared with 98% for control broods and 87% for broods from modified exclosures. Exposure or predation following abandonment was responsible for the greatest number of deaths among radiomarked ducklings (7 and 16 deaths in the 2 years of the study). Predation by raptors was more extensive on radiomarked ducklings attempting to exit intact exclosures (over 2 years, 9 deaths in intact exclosures, 4 deaths in modified exclosures, and 1 death in control broods); additional predation by red fox and Franklin's ground squirrel (*Spermophilus franklinii*) occurred within intact exclosures. While it is not clear whether increased survival of ducklings hatched in exclosures would result in increased recruitment (by day 14, duckling survival rates did not differ among the 3 groups), the authors nevertheless recommended that exits be installed on exclosures.

During a previous year in 2 of the same exclosures (unmodified) used by Howerter et al. (1996), Trottier et al. (1994) found similar results; radiomarked hens and broods within exclosures took more time (average 27.1 hours) to reach a wetland than radiomarked hens and broods in control areas (average 3.1 hours). Three of 18 hens abandoned or lost their broods while attempting to exit a fence. Twenty-three of 32 radiomarked ducklings within exclosures reached a wetland, while 22 of 24 ducklings from control broods reached a wetland. Again, there was no evidence that fence delays had a residual effect on duckling survival (estimated to day 5).

Pietz and Krapu (1994) found that exit designs with 32 single 22- x 16-cm openings used in 3 25-ha exclosures (1 in western Minnesota and 2 in eastern North Dakota) for 2 years resulted in exit times averaging 2.3 hours for 34 gadwall broods and 16 mallard broods; no broods were abandoned and only 3 of 134 radiomarked ducklings died while the hen was trying to exit. Only 2 of 55 hens left exclosures by flying over the fence.

Schultz (1997) examined movements of seven radiomarked hens and their broods in a fence that had an unusually small opening to water on one side of the exclosure. Only 2 of the 7 hens successfully exited the exclosure. The following year, 11 exits (190 m apart; following design of Howerter et al. (1996) were added to the fence. Eight radiomarked hens with their broods were followed; 7 exited successfully from the fence and 1 was killed by a mink before exiting.

Lokemoen and Woodward (1993) compared success of ducks nesting on 20 peninsulas, of which 8 were isolated from mainland by electric fences and 2 by water-filled moats. Isolating peninsulas from the mainland resulted in 3 times the nest success and produces 9 times more ducklings/ha than peninsulas without a barrier from the mainland.

In summary, productivity of ducks can be increased through use of fences in uplands and by isolating peninsulas from the mainland. Characteristics of an area where fence/barrier use is well suited include areas that are attractive to birds, but suffer high nest predation rates. To be effective, fences need to be maintained and predator control within fences is necessary. For fences other than peninsula cut-offs, exits for hens should be located on all sides of the fence at reasonable intervals. Fences, although costly to construct, require minimum maintenance (Greenwood et al. 1990, Lokemoen and Woodward 1993, Lokemoen 1994) and endure for many years. When the costs are considered over the expected life of the fence, this method often is more cost effective than other techniques (Lokemoen 1984, Lokemoen and Messmer 1994, Goodrich and Buskirk 1995).

Nest Structures

Are nest structures effective management tools, and what should be considered in application of structures?

Artificial nesting structures allow managers to effectively avoid the problem of mammalian predation on ground nests by removing nests from the reach of predators. Nest success of >70% has been reported in many studies (Bishop and Barrat 1970, Doty et al.1975, Doty 1979, Higgins et al. 1986, Ball and Ball 1991, Eskowich et al. 1998, Artmann et al. 2001). Consistently higher nest success in structures than in ground nests, combined with strong homing behavior of some duck species (e.g., mallard), give nesting structures the potential to significantly increase duck production in local areas

(Haworth and Higgins 1993). However, as Ball and Ball (1991) pointed out A . . . using artificial nest structures to increase nest success is, in reality, treating a symptom. The causes of low nest success are loss, degradation, and fragmentation of nesting habitat in conjunction with man-induced changes in predator communities. Structures do not treat the fundamental causes, nor do they benefit most species of ground-nesting birds.@ Mallards are by far the most common prairie duck inhabitant of nesting structures, but use by other duck species, including redhead (*Aythya americana*), blue-winged teal, gadwall, northern pintail, canvasback (*A. valisineria*), lesser scaup (*A. affinis*), northern shoveler (*Anas clypeata*), and ruddy ducks (*Oxyura jamaicensus*) has been observed (Bishop and Barrat 1970, Doty et al. 1975, Haworth and Higgins 1993, Eskowich et al. 1998, Yerkes and Kowalchuk 1999).

To maximize benefit provided by nesting structures, options associated with installation and maintenance must be considered, including structure type, location in the landscape, placement and density of structures in a wetland, and initial and annual costs. Artificial nesting structures have the advantages of being cost-effective, applicable on private land, and acceptable to the public (Artmann et al. 2001), but have suffered from low occupancy (Sidle and Arnold 1982) and been targeted by predators in some situations (Doty et al. 1975).

A variety of different nesting structures have been used, including baskets, cones, cylinders (tunnels or Ahen houses@), earth-filled culverts, and hay bales, all of which provide the essential lateral cover and nesting material to attract breeding mallards. Structures are normally placed in semipermanent or permanent wetlands near the edge of the vegetation/water interface. One structure type is not clearly superior to others; consideration must be given to costs of initial materials, construction, and maintenance and to structure longevity. In a one-year study of paired nesting structures in the parklands of Saskatchewan, mallard hens preferred tunnels to baskets in 90 of 92 cases where preference could be determined (Eskowich et al. 1998). Walsh (1990, in Johnson et al. 1994) noted that bales were the only type of nesting structure that predators could easily climb. In an evaluation of baskets, bales, and culverts, Johnson et al. (1994) found that both bales and culverts were significantly more attractive to mallards than baskets; they recommended culverts as the best structure type for increasing mallard populations in the PPR, but noted that all structures were valuable to breeding waterfowl.

Hay bales are an inexpensive but short-lived option. They are readily available and less expensive, initially, than other structure types. Bales are used by both nesting ducks and geese, provide loafing sites and habitat for other wildlife, and are biodegradable. However, they can be difficult to place in the wetland, cannot be used where water levels fluctuate excessively, and usually need to be replaced every 2 to 3 years (Zenner et al. 1992).

Post structures like baskets, cylinders (hen houses), and cones have higher initial costs but generally last for many years (nest basket life expectancy can exceed 20 years, Haworth and Higgins 1993). Cylinders and cones may provide additional cover and protection from avian predators than the more exposed baskets. Annual maintenance to replace nesting material is essential; occupancy is unlikely if nesting material is not available.

Although cement culverts require periodic checks to make sure that soil levels do not settle below the rim, they have the advantage of being largely maintenance free and annual vegetation growth in the soil substrate should provide adequate nesting cover. To prevent monopolization by earlier nesting Canada geese, large culverts can be dissected by a covered partition to provide sites for simultaneous nesting of Canada geese and mallards (Ball and Ball 1991). Heavy machinery and good spring ice conditions are required for installation and, like other structures, culverts may be damaged or tipped by shifting ice.

Nesting structures are not immune to predation, although steps may be taken to reduce the probability that predators will notice or access nests. Many studies have reported very few instances of predation (Bishop and Barrat 1970, Ball and Ball 1991, Yerkes and Kowalchuk 1999, Artmann et al. 2001). However, nest baskets in two study areas in North Dakota received increasing predation by gulls over a five-year period, with nest loss rising from 2% to 23%; in one nesting season, an area of high density baskets suffered 86% nest loss (Doty et al. 1975). Structures need to be high enough above the

water that mammalian predators cannot easily gain access, but not too high, or they may serve as perch sites for raptors, which may decrease occupancy (Bishop and Barrat 1970). To reduce the likelihood of mammalian predators gaining access, structures should be 0.5-1m above water level (see Haworth and Higgins 1993) and >15m from shore (Zenner et al. 1992); a predator guard of plastic pipe may be placed around the support post of baskets, cones, and cylinders (Artmann et al. 2001).

Structure location may also influence depredation of broods. Twenty-six of 58 (44.8%) radioed ducklings died in the two years of a study investigating the survival of broods and ducklings hatched from nests in artificial structures in eastern South Dakota (Stafford et al. 2002). Of 11 cases of known or suspected depredation on radioed ducklings, 4 were attributed to great horned owls, 3 to raccoons, 2 to red fox, and 2 to mink. Of the 4 best models for predicting duckling survival (based on Akaike's information criterion; Burnham and Anderson 1998), all included a variable for mean estimated percentage of wetland surrounded by large trees. The authors recommend that, in nonforested landscapes, nest structures not be placed in wetlands with minimal emergent escape cover that are surrounded by tall, mature trees. This study also reflects the need to monitor structures and brood survival. Authors report only 1 duckling fledged of 51 ducklings produced by marked females on a single wetland. The nesting structures were essential acting as sink habitat. This 2.6 ha wetland was, deep with little emergent cover and surrounded by large trees that were used by great horned owls and other raptors.

In most cases, however, the greatest hindrance to success of nesting structure programs has been low occupancy. While high mallard occupancy has occurred in some situations (100% in 1 culvert over 11 years in eastern North Dakota, [Higgins et al. 1986]; 70% in 167 cylinders in Saskatchewan [Eskowich et al. 1998]; 36-59.4% among sites and years in cylinders in Manitoba [Yerkes and Kowalchuk 1999]), most reported occupancy rates have been lower. No ducks nested in 29 cones and 102 cylinders that were monitored for 2 breeding seasons in eastern North Dakota (Sidle and Arnold 1982). Only 11.4% of 260 cylinders available for 2 breeding seasons (492 cylinder years) in northeastern North Dakota were occupied (Artmann et al. 2001). Occupancy may be particularly low during drought periods (Doty et al. 1975, Ball and Ball 1991).

In the parkland of Saskatchewan, Eskowich et al. (1998) placed 2 types of nesting structures in wetlands in landscapes with limited surrounding nesting cover and found high occupancy rates (70%) and nest success (>90%) in cylinders. They suggested that, while some management efforts aimed at areas where nesting success is low may be counterproductive by encouraging ducks to settle where there is low probability of nesting success (Greenwood et al. 1995), the use of nesting structures in these areas, assuming that brood rearing habitat is adequate, may actually increase nest success.

On the other hand, in northeastern North Dakota, occupancy rates of cylinders were >4 times higher on grassland sites (17.8%) with high amounts of perennial cover than on cropland sites (3.9%) with low cover amounts, but wetland habitat was comparable (Artmann et al. 2001). The difference was attributed to higher mallard pair densities in areas with more cover, suggesting that initial nesting structure occupancy can be maximized by placing structures in areas with high pair densities. Relative efficiency of structures was estimated to be >3 times greater with high occupancy rates, even when only incremental successful nests (those that hatched in nesting structures in excess of the number that would be expected to hatch under typical ground nesting conditions) were considered.

In summary, nesting structures provide attractive and secure nesting sites for mallards; however, survival of ducklings hatched on structures is poorly documented. Furthermore, placement of structures in areas of high mallard pair density to increase rates of occupancy is recommended. Wetlands should include safe brood habitat. Capital investment per structure is modest, but the cost per occupied structure can be high (Lokemoen 1984, Artmann et al. 2001). One other advantage of structures is that application is apparent to the public, results are easily determined, and structures can be installed by untrained individuals at low cost, thus the method lends itself to public involvement.

Predator Control

Is predator control an effective management tool, and what should be considered in application?
Predation is the major reason for nest failure, thus logic follows that thorough removal of the predators causing the problem will result in increased nest success. Several studies, not surprisingly have shown intensive lethal methods (e.g., toxicants, traps, shooting) can substantially decrease predation rates on duck nests (Balser et al. 1968, Duebbert and Lokemoen 1980, Greenwood 1986, Sargeant et al. 1995, Garrettson et al. 1996). All inclusive predator removal benefits all duck species in all habitats and costs are relatively modest. Furthermore, there is evidence to suggest that nest density increases where nest success is high (Duebbert and Lokemoen 1980), which would additively benefit areas where removal is conducted. The reasons for increases in nest density are not known, but they could be related to birds returning to a safe place, or perhaps to a population increase. But, predator removal remains controversial, especially humane aspects and appropriateness of killing predators to provide ducks for hunters, and thus, management agencies restrict its use. Moreover, restrictions on types of methods that can be used, the manner of application, and species that can be removed increases the difficulty and effectiveness of predator removal as a management tool.
Despite the strong evidence that predator removal is effective in increasing nest success, there is no guarantee that removal will invariably improve nest success rates. Greenwood (1986) reported that overall duck nest success increased from 5% on control sites to 15% where striped skunks were removed; however, no significant change occurred on several of his individual study sites where other nest predators were especially common. In a preliminary year of a comparison of sites with partial removal of predators (skunks and raccoons only) versus complete removal (skunks, raccoons and red foxes) versus control areas (no removal), nest success was 23% on the partial removal site, 36% on the complete-removal site and 31% on the control site (Delta Waterfowl Report 1999 Research Projects in Review, Vol. 1999, Issue IV). Although this is an inadequate sample, to assess statistical significance, it does illustrate the variability that is inherent in results.
Literature is replete with examples of how mammalian predator species respond to losses of individual members of populations (Sargeant 1972, Anderson 1988, Sandell 1989). For example, territorial species such as red foxes frequently adjust space use to occupy vacated parts of the landscape (Sargeant 1972). The ability of coyotes to increase litter sizes when subjected to population reduction also is well documented (Knowlton 1972). These responses of predators to removal as a management option might ultimately result in a low net positive effect for waterfowl over time. More research is needed to evaluate long-term benefits and detriments of removal methods.
The following factors are important to ensure the success of a removal program to enhance duck nest success. First, studies indicate that the most effective predator control is when it is applied on a large scale rather than on small areas (Sargeant et al. 1995, Garrettson et al. 2001). In small areas, the vacancies created by the removal are quickly (often within days) filled by other individual predators into the area and inner core areas remain free of predators for a longer period. Second, removal of predators is most appropriate in areas with high pond and breeding pair densities (Sargeant et al. 1995). That is, removal would be best conducted where potential duck production is high and where nest success is low due to predation. Third, removal of predators must occur each year in early spring and continue through the nesting season (Sargeant et al. 1995). Fourth, trappers should be allowed flexible work schedules and the use of as many tools as are available (Sargeant et al. 1995, Garrettson et al. 2001). Finally, programs should emphasize the quality of the removal efforts, not the numbers of predators removed. It is the number of predators left on the site that is important, not the numbers of predators that have been removed.
Despite the effectiveness of predator control there are other factors that must be considered before implementing a predator removal effort. Predator control often is opposed by the public, even to protect endangered species, and will be difficult to implement because of social constraints (Goodrich and Buskirk 1995). Toxicants, the most effective control method, require an extraordinarily expensive

process to register compounds, deterring the development of new control agents. Other issues to consider include humane treatment of animals, ethical concerns, and anti-hunting and anti-trapping sentiment (Kirkpatrick and Turner 1985). To enhance duck production, predators would have to be controlled each spring at a time that fur has little value. Thus, there are serious ethical concerns for wildlife managers who would be forced to advocate wasting a valuable fur resource to enhance production of ducks to be harvested by other users. Information is not available regarding the long-term impact of predator control on passerines and other species; however, Dion et al. (1999) reported that in the short-term passerine nest success is not affected by predator removal. Finally, there are no long-term benefits because redistribution, dispersal, and compensatory reproduction by predators require extensive control of predators every year.

Reproductive Inhibitors

Are reproductive inhibitors effective for managing predators and predation?

      Inhibiting reproduction is an appealing nonlethal approach to population management of wild animals (Kirkpatrick and Turner 1985, Warren 1995). With carnivores, inhibition of reproduction has been suggested to reduce predation by decreasing food demand of females because they are not providing for young. Moreover, carnivore recruitment would be reduced, thereby decreasing population size. However, these assumptions are not necessarily correct. Female skunks without young behave differently than females with young, by not remaining close to their den sites when foraging. Female skunks without young, move further distances and for longer periods, which is more similar to movements of male skunks, and thus they having opportunity to encounter more nests (R. J. Greenwood and A. B Sargeant, unpublished data). This is also the likely situation for other predators such as badgers (Lampe and Sovada 1981). Another important consideration in use of reproductive inhibitors is the proportion of a population that remains reproductively active after treatment (Garrott 1995). This is influenced by the proportion of animals detected, the proportion detected that are treated, and the efficacy of the agent. Ideally a population to be managed should be isolated geographically to limit immigration and emigration (Garrott 1995). There are few isolating mechanisms among predator populations in the PPR. In addition, reproductive and/or dispersal characteristics of some carnivores in the region (e.g., red foxes, raccoons, striped skunks) permit rapid recovery from population depletion.

      Among canids, compounds tested or suggested for inhibiting reproduction range from steroids to immunocontraceptive vaccines (Kirkpatrick and Turner 1985). Vaccines offer short-term reversible contraception suitable for rare or highly valued species, but might not be adequate where long-term population control is required or where the goal is dramatic reduction of the population (Garrott 1995). Where long-term control is desired, a technique that results in permanent sterility is more appropriate. However, widespread use of treated baits that might result in permanent sterility is unlikely to be popular with the public, especially where domestic animals might be exposed. Furthermore, Kirkpatrick and Turner (1985) questioned whether unforeseen side effects of reproductive inhibition might be worse that the problem, and suggested extensive preliminary studies are necessary, species by species, to assess treatment effects before field application is attempted.

Buffer Prey/Supplemental Food

What do we know about the abundance and availability of buffer preys influencing predation pressure on nesting ducks and is supplemental feeding an effective management tool?

      Despite the significant amount of literature documenting the effects of predators on nesting waterfowl, there is no clear view of the complex predator-prey relationships in the grassland-wetland ecosystem. Both positive (Verts 1967, Rusch et al. 1972, Byers 1974, Beintema and Muskens 1987) and negative (Roseberry and Klimstra 1970, McInvaille and Keith 1974, Klimstra and Roseberry 1975,

Pehrsson 1986, Summers 1986) relationships between nesting success and alternative prey abundance have been reported from research in temperate regions. There is a common assumption and some evidence that indicated nest success will increase when alternative prey sources, such as small mammals, are abundant in/around nesting habitats (e.g., Byers 1974, Weller 1979, Pehrsson 1986, Beintema and Muskens 1987, Marcstrom et al. 1988). But in fact, it is equally reasonable to surmise that high prey densities attract predators and may lead to increased predator reproductive rates, both of which would be expected to increase localized foraging pressure (Klimstra and Roseberry 1975, Wilson and Bromley 2001). Even if we assume that predators switch to abundant alternative prey, nest encounters and opportunistic nest depredations will occur if nests are located in the same habitats as alternative prey. Furthermore, if abundant alternative prey leads to increased predator populations, nest predation will likely remain high if alternative prey decline and predators must forage more heavily on other prey items (Wilson and Bromley 2001). Several studies have noted increased nest predation rates as predators forage over larger areas, and encounter and destroy more nests, after formerly abundant small mammal populations decline (Pehrsson 1986, Beintema and Muskens 1987, Marcstrom et al. 1988, Jarvinen 1990, Wilson and Bromley 2001).

It is important to recognize that ducks are not the major food source for predators in the region; mammalian predators of ducks preferably forage on small mammals and insects. Typically mice and voles are the predominate prey of red foxes; badgers respond more directly to changes in the abundance of ground squirrels and gophers; and insects are most important to skunks during the spring and summer. Those are the food items that attract predators into areas, and encounters with nests are secondary. However, there may be a point of high nest density, that predators such as foxes, could be drawn an area because of the nests. But, if we take this one step further, there may be a point in which densities are high enough that predators are satiated, i.e., there is a limit what impact predators are able to confer.

In a study of supplemental feeding targeting striped skunks, Crabtree and Wolfe (1988) reported that provision of supplemental foods for striped skunks reduced predation on duck nests located on dikes on a Utah refuge. However, a similar study conducted in central North Dakota, failed to confirm that nesting ducks benefited from the provisioning of supplemental foods to striped skunks during the nesting season (Greenwood et al. 1998). Greenwood et al. (1998) observed a yearly tendency for higher nest success rates on the provisioned areas (0 ' 46%, 1993; 36%, 1994) than on control areas (0 ' 27%, 1993; 31%, 1994); but, mean nest success rates overall did not differ between food-supplemented areas (0 ' 41%) and control areas (0 ' 29%; *P* ' 0.27). Striped skunk depredation rate was lower on food-supplemented areas (11%) than on control areas (24%), suggesting that skunks reduced their consumption of eggs when provided with a food supplement. In 1994, habitat conditions were optimal, and ducks nested persistently into the summer when nest success rates of food-provisioned areas and control areas differed by only 5 percentage points. That year American badgers and Franklin's ground squirrels apparently compensated for reduced depredation by skunks. Thus, although skunks and other mammalian predators seem to have responded positively to food supplementation, nest depredations overall did not change. Provision of supplemental food apparently has limited value for managing depredation of upland duck nests in the PPR where predator communities are complex.

Obviously, a better understanding of the effects of small mammal abundance on waterfowl nest predation rates would be beneficial to waterfowl researchers, managers, and conservationists. It is a topic in need of further research because of the many unanswered questions and complexities of the relationships. Both Ducks Unlimited's Institute for Waterfowl and Wetland Research and Delta Waterfowl Foundations have ongoing graduate student projects in this area.

Alter Structure or Distribution of Wetland Vegetation

Can management of wetland vegetation influence predation pressure on nesting ducks?

We don't know of any available information addressing whether structure or distribution of wetland vegetation influences predation pressure.

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Part IV-Appendix

SPECIES ECOLOGY
Marsha A. Sovada and Molly J. Burns

Red Fox (*Vulpes vulpes*)

Distribution and Abundance

The red fox is the most widely distributed fox in the world (Voigt 1987) and is found in a wide variety of habitats, including much of the PPR of North America, especially in eastern and southern areas (Sargeant et al. 1993). Historical changes in red fox populations in the Region are related to dynamics of the canid community, especially as related to human activity (see Johnson and Sargeant 1977). Foxes were scarce throughout the region before settlement, increased for a short time after settlement began (following the extirpation of wolves [*Canis lupus*]), and then decreased in numbers as coyote (*C. latrans*) populations increased. Red foxes were sparse to absent through much of the region from the 1890s to the mid-1930s (Johnson and Sargeant 1977). Beginning in the 1930s, red fox populations expanded greatly in the PPR (Johnson and Sargeant 1977). This increase is attributed to the decline in coyotes, Amaking room@ for the expanding fox population.

At a local scale, where foxes live sympatrically with coyotes, coyotes can influence the distribution of foxes through interspecific competition. Foxes avoid the core areas of coyote territories where the risk of encounter between the species is greatest. Interference competition (i.e., intimidation) is the mechanism in this relationship (discussed below). However, coyotes also occasionally chase and kill foxes. Interspecific strife between coyotes and red foxes likely is the reason that foxes often are present and den close to human habitation, road ditches, and other places of human activity. Because coyotes avoid these areas, they afford a zone of safety for foxes. Young foxes dispersing through coyote territories have a difficult time finding a place to settle and survival rates of young foxes during dispersal is low. Spatial separation between foxes and coyotes is most apparent during the pup-rearing periods of spring and summer.

In recent years, sarcoptic mange caused by *Sarcoptes scabiei* has been responsible for epizootic disease in populations of canids in Minnesota, North Dakota, and South Dakota. Although short-term mortality rates due to mange are high, mange generally has minimal long-term effect on populations. In some areas where mange has affected fox and coyote populations, the later have recovered more rapidly, thus affecting the ability of red foxes to reoccupy the area.

Home Range

Red foxes live in family groups consisting of a mated pair and occasionally a third adult, usually a yearling female offspring that delayed dispersal. Families occupy well-defined, non-overlapping, contiguous territories (Sargeant 1972). Fox families are highly territorial in spring and summer, with discrete territories ranging in size from 3 to 21 km^2 (Sargeant et al. 1993). Territory borders are generally similar throughout the year. Territory size is inversely related to population density (Sargeant 1972,

Trewhella et al. 1988), with territories expanding (filling empty space) and contracting as population size fluctuates. However, the presence of coyotes can also influence spatial arrangement and density of foxes. Although very few reports of actual antagonistic behavior between fox and coyote exists (Sargeant and Allen 1989), coyotes nonetheless exclude red foxes from the core of the large coyote territories; fox territories generally are on the periphery of coyote territories (Sargeant et al. 1987).

Reproduction and Dispersal

Red foxes breed in January and February. In the eastern PPR, with relatively low densities of foxes and adequate prey resources, most yearling and adult foxes breed each year (Voigt 1987), but older foxes have greater reproductive performance. Females in North Dakota have 4 - 6 pups in March or April (Allen 1984) after a 53 day gestation period. A litter of 17 was reported in Michigan (Holcomb 1965). Pups emerge from the den in early May and initially remain near the den; distance ventured from the den gradually increases until dispersal begins in August. Dispersal peaks during October and November, continuing through January. A study in Europe reported a positive correlation between mean dispersal distance and mean home range size, suggesting that dispersing foxes travel in increments of home range diameters (Macdonald and Bacon 1982).

Dispersal in red fox includes both young foxes leaving their natal areas and adult foxes emigrating, sometimes from territories where they have successfully raised a litter. Allen and Sargeant (1993) found that mean recovery distance and percentage of foxes recovered that had dispersed increased with age class and were greater for males than for females; dispersal distances of >300 km were reported.

Mortality

Most mortality is the result of hunting, trapping, or vehicle collisions. In the past 10 years, however, secondary infections and weakened condition resulting from sarcoptic mange have been major factors contributing to fox mortality in Minnesota, North Dakota, and South Dakota.

Activity

Red foxes are largely nocturnal, but may be active during daylight hours. Both sexes actively raise their pups, but foxes are solitary in their movements, foraging, and territorial maintenance. Each adult fox of a pair will thoroughly cover the entire family territory over the course of 2 weeks (Sargeant 1972). However, areas of intense activity within the territory might vary throughout the year. Activity is concentrated near the rearing den while pups are young. Commonly, more than 1 rearing den will be used during pup rearing. As pups become more mobile, litters may be split and 2 dens will be used concurrently. Human activity near a den will often cause adults to move pups to a new den site.

Food Habits

Foxes are largely carnivorous, although they opportunistically take advantage of a variety of food resources (Sargeant 1978, Sargeant et al. 1986, Voigt 1987). They consume more small mammals (e.g., voles, mice, rabbits, hares, and sciurids) than any other food, although they supplement this diet with a wide variety of other food items, such as plants, birds, eggs, and carrion. Red foxes take eggs and ducklings, and prey selectively on female dabbling ducks, particularly early-nesting hens (Sargeant et al. 1984). Red foxes are considered a principal, if not the principal predator, of duck nests (Sargeant et al. 1984, Johnson et al. 1989). Prey remains are seldom left at the nest, because foxes nearly always cache eggs away from the nest and either cache adult birds or carry them to the natal den for the pups. An especially important aspect of red fox predation is that foxes cache eggs and adults for future use rather than eating them at the nest site (Sargeant et al. 1998). Caching behavior magnifies the impact of foxes on duck nests relative to immediate food needs of this predator.

During winter months, the diet consists mostly of rodents, including mice and voles. However, Sargeant et al. (1986) found that in North Dakota, some foxes consumed large quantities of commercial sunflower seeds that are found as waste in harvested fields. Birds (probably from caches), insects, amphibians, rabbits and hares, and deer (likely scavenged) also were eaten.

Habitat Use

Red foxes are well adapted to prairie environments and to coexistence with humans (Johnson and Sargeant 1977). Multiple habitats throughout the region are suited to foxes and they seem to thrive in intensive agricultural areas found in the PPR of Minnesota and the eastern Dakotas (Sargeant et al. 1993).

Red foxes forage primarily in upland habitats. Wet meadow edges of wetlands are particularly attractive to foxes (Phillips et al. 2003), likely because of the diverse and abundant food resources found in this habitat. Foxes tend not to enter water, thus nest overwater are seldom threatened by red foxes (Sargeant et al. 1998).

In landscapes with highly fragmented grassland, foxes thoroughly use small isolated patches of grassland (see Greenwood et al. 1995, Sovada et al. 2000). Sovada et al. (2000) reported that red fox activity indices tended to be negatively correlated with grassland patch size and also with coyote indices, whereas coyote indices tended to be positively correlated with patch size. This suggests that, in areas of large grassland tracts, the effect of red foxes on nest survival might be mediated by presence of coyotes. This is supported by a study that found nest success of ducks was higher in areas occupied coyotes than areas occupied by red foxes (Sovada et al.1995).

Phillips et al. (2003) demonstrated that in the fragmented areas (15B20% grass), red foxes selected the edge and core areas of grasslands as well as along wetland edges for foraging, whereas in continuous areas of grass (45B55% grass), they did not select interior areas of grassland (i.e., core areas of planted cover or wetland edges in cover) as frequently as edges of planted cover. Overall, these results all suggest that the restoration and management of large blocks of grassland, particularly in landscapes that already have a high composition of grassland, would be beneficial for nesting ducks.

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Coyote (*Canis latrans*)

Distribution and Abundance

Coyotes are found throughout the United States, including the PPR. It is difficult to estimate coyote densities, but we do know that they are highly variable (Voigt and Berg 1987). Knowlton (1972) estimated that densities of 0.2в0.4 coyotes/km^2 were common over much of the range, but densities seem to be much lower in much of the PPR. Winter densities of coyotes in Minnesota were approximately 0.2 coyote/km^2 (Berg and Kuehn 1986). In North Dakota, Sargeant et al. (1987) reported sizes of coyote family territories averaged 61 km^2, translating to 0.03в0.07 adult/km^2. Densities seem to have increased in North Dakota since 1987 with current coyote densities in Minnesota and North Dakota likely between estimates by Voigt and Berg (1987) and Sargeant et al. (1987), although no recent data are available.

Home Range

The basic unit in coyote social organization is the family (mated pair plus pups and occasionally 1 or more associated adults) occupying a territory. Adult females, mated pairs, or groups of coyotes may defend territories; defense is most common during the denning season. Families will occupy territories in the same area for consecutive years. In North Dakota and likely Minnesota, typical coyote families occupy mostly contiguous and non-overlapping territories (Sargeant et al. 1987). Home range size is inversely related to coyote abundance. In a low-density population in North Dakota, home range size averaged 61 km^2 in spring-summer and 30 km^2 during fall-winter (Allen et al. 1987). Home ranges of territorial individuals ranged from 5 to 80 km^2 and included most of the family territory (Sargeant et al. 1993). The population also contained a few transients (single animals without litters), who occupied much larger home ranges (Allen et al. 1987).

Reproduction and Dispersal

Breeding takes place from January to March (Voigt and Berg 1987). Mated pairs may produce pups each year and both the male and female raise the pups, occasionally with help from an unmated adult (yearling offspring). Average litter size is about 6 (Beckoff 1977). Percentage of yearlings that breed varies among region and years (Voigt and Berg 1987). Prey abundance affects both density and reproduction of coyotes (Voigt and Berg 1987). Dispersal takes place in autumn and winter when pups are 6 to 9 months old. Dispersal distances can be as great as 80в160 km. Not all pups disperse in their first year, which may explain the presence of adult helpers at some dens (Beckoff 1977, Voigt and Berg 1987).

Mortality

Coyotes are most vulnerable during their first year, as indicated by higher mortality rates for juveniles (40в70%) than adults (30в50%; Voigt and Berg 1987). Human-caused deaths account for most mortality, but diseases and parasites, including distemper, canine hepatitis, and sarcoptic mange, are important at times (Voigt and Berg 1987).

Activity

Coyotes are primarily nocturnal, but may be active during the day (Beckoff 1977). Generally, activity and movements such as foraging and territorial maintenance are most common at night (Gipson and Sealander 1972, Voigt and Berg 1987). Daytime activity might increase during the breeding season (Andelt 1985) and pups are more active than adults during the day (Gipson and Sealander 1972).

Coyotes are less likely to form packs than are wolves, but they often forage in pairs or threesomes. The prey of coyotes seems to determine group size, with larger prey items (e.g., ungulates) requiring a larger hunting group. In the PPR, smaller food items (rodents, rabbits, fawns) are readily available and used by coyotes, thus precluding the need for larger hunting groups.

Coyotes will use underground dens for birthing young, but resting sites during other seasons tend to be sheltered areas above ground.

Food Habits

Coyotes, although essentially carnivorous, are versatile in their eating habits and are considered opportunistic predators. Their diet changes throughout the year in response to available food sources (Brillhart and Kaufman 1994, Sovada et al. 2000). Mammalian prey are important year-round and are supplemented in spring, summer, and fall with plants, insects, and birds (Brillhart and Kaufman 1994, Lewis et al. 1994). Some prey items are cached for later consumption. Small mammals are the primary prey source during the summer (Sovada et al. 2000). In winter, larger prey including deer, livestock carrion, and lagomorphs, constitutes the majority of the diet (Beckoff 1977, Voigt and Berg 1987). Coyotes will eat adult birds and eggs, but they are not considered to have as great an impact on nesting birds as red foxes (Sovada et al. 1995).

Habitat Use

Coyotes are adaptable and may use a wide range of habitats, including forests, clear cuts, and farmland, and they prefer areas not occupied by wolves. In North Dakota, coyotes prefer large areas of grassland and avoid areas of human activity; coyote families center their activity on the most roadless areas where cropland was least abundant (Sargeant et al. 1987, Sargeant et al. 1993). However, Sargeant et al. (1993) also observed in North Dakota, coyotes occupying several intensively farmed areas, demonstrating the suitability of intensively cropped habitats for coyotes also. The apparent habitat-related differences in distribution of coyotes throughout North Dakota probably reflects differences in their survival rates from human-inflicted mortality more than differences in habitat suitability. In Nebraska, coyotes preferred wooded and native-grass fence lines, draws, and fields for hunting and resting. Much of the distance traveled in a night was across large, agricultural fields while coyotes were in route between preferred habitats (Andelt and Gipson 1979).

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Raccoon (*Procyon lotor*)

Raccoons are a common predator in the Prairie Pothole Region (PPR), but population densities tend to be lower and average home range sizes are larger in the PPR than elsewhere (e.g., eastern states). In Minnesota, raccoons are least abundant in grasslands, gradually increase in numbers in the transition to woodland, and are most abundant in woodland areas. In the prairie, raccoons spend little time foraging in grasslands concentrating their activities at wetlands and farmyards or in upland sites where seeds from agricultural crops are available (Fritzell 1978b, Greenwood 1981). Thus, duck nests in or near wetlands are at greatest risk to depredation by raccoons (Sargeant and Arnold 1984).

Distribution and Abundance

The northern portion of the PPR is near the northern limits of the geographic distribution of the raccoon (Lotze and Anderson 1979). At the time of settlement, raccoons occupied only the wooded hills and river valleys in the southeastern portion of the PPR and were nearly absent throughout the entire PPR of Canada, except portions of southern Manitoba (see Sargeant et al. 1993). Because raccoons are well suited to coexisting with humans, they have benefited from agricultural development in the PPR. Expanding agricultural activities provided abundant resources not available for raccoons prior to human settlement, including buildings for resting and rearing young and cereal grains for food. Additionally, planting of trees and encroachment of shrubs and trees in the prairies has benefited raccoons by providing shelter and escape from coyotes. Following settlement, raccoon populations became more widely distributed throughout the PPR of the United States and since the 1950s populations have expanded into prairie Canada (Sargeant et al. 1993). Population densities are difficult to estimate. Raccoons have been reported to occur at relatively low densities in much of the PPR (North Dakota, 0.5в1.0/km^2, Fritzell 1978a; Manitoba, 10.1/ km^2, Cowan 1973) compared to estimates of 31 raccoons/km^2 in Mississippi (Yeager 1937).

Home Range

Adult raccoons are primarily solitary, but may be found together around concentrated food sources, during the mating season, and while denning over winter. Home ranges vary greatly depending on habitat, population density, and food supply. Raccoons in the prairies have larger home ranges than elsewhere (Sanderson 1987, Sargeant et al. 1993). Adult males occupy the largest home ranges, averaging >25 km^2 in North Dakota (Fritzell 1978a). Although nearly exclusive of other adult males, these ranges may encompass the entire range of multiple females. Home ranges of adult females and yearlings are considerably smaller (7в13 km^2) and may overlap considerably with those of conspecifics (Geis 1966, Fritzell 1978a). Raccoon populations in the prairies of western Minnesota likely are similar to those of North Dakota, but as populations transition into wooded areas, densities likely increase and home range sizes probably decrease.

Reproduction and Dispersal

Studies across the breeding range of raccoons have revealed substantial variability in reproductive biology. Breeding ages, whelping dates, and litter sizes have been shown to vary with latitude, habitat, and density (Cowan 1973; Fritzell 1978c, 1985; Clark et al. 1989). Reproduction in northern latitudes is characterized by delayed maturity and large litter size (Fritzell 1978c). Fewer yearling females (38B77%) reproduce than adult females (84B100%; Fritzell 1978c, Clark et al. 1989). In southeastern North Dakota, Fritzell (1978c) reported that only 2 of 14 yearlings had reproduced, in contrast to 26 of 28 adults. Breeding occurs early in northern latitudes (February-March in Minnesota and North Dakota); average whelping date is around 8 May (range mid-April to mid-June; Cowan 1973, Fritzell 1978c). Average litter size of adult females is about 4.3 young, with individual litters of 3 - 7 (Cowan 1973, Fritzell 1978c, Clark et al. 1989). Litter size tends to increase with age of the female and northern latitude (Lotze and Anderson 1979, Clark et al. 1989).

Family groups (female and young) remain together through the summer until weaning in July or August (Cowan 1973) and may den communally in winter (Mech and Turkowski 1966). Although fall dispersal has been documented in Ohio and Iowa (Urban 1970, Clark et al. 1989), in northern latitudes it is likely that most young disperse in spring (May-June; Cowan 1973, Fritzell 1977, 1978a). Young raccoons may disperse >30 km; in Iowa, Clark et al. (1989) found an average dispersal distance of 15.1 km. It is common, however, for young females to remain in their natal area.

Mortality

Overwintering and dispersal represent periods of greatest vulnerability for raccoons. Cowan (1973) found >50% mortality for the entire population and up to 60% mortality in yearling raccoons in Manitoba. In the Cedar Creek area of central Minnesota, 13 of 28 raccoons that died over the course of a year died of starvation or extreme parasitism; most of these were juveniles (Mech et al. 1968). However, anthropogenic causes, including hunting, trapping, and vehicle collisions, account for the majority of mortalities, particularly in heavily exploited populations (Fritzell and Greenwood 1984, Clark et al. 1989). Predation is not a significant cause of mortality, however, Clark et al. (1989) found that coyotes occasionally kill raccoons. Circumstantial evidence suggests that coyotes may suppress raccoon populations in the PPR (Cowan 1973, Stelfox 1980).

Activity

Raccoons are largely nocturnal, but occasionally are active during the day. Nightly foraging activity in central North Dakota was characterized by extended periods of localized foraging interspersed with long-distance travel (Greenwood 1982). Adult males travel further than other raccoons. Diurnal resting sites change daily (Mech et al. 1966), except for those of females with young, whose foraging areas and denning locations are restricted to areas around the rearing den.

Raccoons remain active well into fall. Weight gain during this time is critical for overwintering success, as it is common for raccoons to lose 30B50% of their body weight over the winter (Mech et al. 1968, Cowan 1973). Glueck et al. (1988) found that severe winter weather eventually caused raccoons to retreat to winter dens, commonly located in or under buildings, scrub piles, cellars, burrows, or trees (Mech et al. 1966, Cowan 1973). Although raccoons do not hibernate, they may remain dormant for extended periods during cold weather.

Food Habits

Raccoons are omnivores, their opportunistic feeding habits reflecting seasonal and annual abundance of food resources (Schoonover 1951, Greenwood 1981). During the 1974-1976 waterfowl nesting season in central North Dakota, Greenwood (1981) found plant material, largely cereal grains, in 84% of raccoon scats and animal remains in 86% of scats. Birds occurred in 21-49% and egg shell remains in 16-38% of scats each year. Ducks and coots (*Fulica americana*) could be identified in 5% and 6% of scats, respectively. Of the 64 large birds found in scats, 55% were coots (adults and chicks) and

41% were ducks. Evidence suggested that most large birds were scavenged. Duck eggs were identified in 7-14% and coot eggs in 1-10% of the scats each year (Greenwood 1981, 1982). In early spring, grain and livestock feed obtained at farmyards was an important supplement to the limited naturally-occurring food sources. As the season progressed, habitat use shifted to exploit increased production and availability of wetland-related foods, such as amphibians, invertebrates, and nesting waterbirds (Fritzell 1978b). Overwater-nesting birds are particularly vulnerable to raccoon predation. Although raccoons traveled through grassland and cropland between foraging sites, these 2 habitats were not preferred for foraging (Fritzell 1978b, Greenwood 1982). However, wheat, barley, and corn crops have been identified as an important component of the raccoon diet in some areas and during some seasons (Geis 1966, Lotze and Anderson 1979, Greenwood 1981).

Habitat Use
Typically, all raccoons in the prairies forage in the same habitats and use the same foods (Greenwood 1982). During the day, raccoons bed in thick vegetation of pond edges, abandoned buildings, or other places of shelter (Mech et al. 1966, Cowan 1973). Rearing dens are often found in farmyards, where haylofts, attics, and buildings are commonly used (Fritzell 1978b, Cowan 1973). Because females with young restrict their activities to areas around their den, waterfowl nests located in the smaller, more thoroughly covered ranges of female and yearling raccoons may be at greater risk of depredation than those occurring in ranges of adult males, particularly those nests in close proximity to rearing dens (Fritzell 1978b).
Nightly foraging by raccoons may include trips to farmyards and wetlands, often several kilometers apart (Fritzell 1978b, Greenwood 1982). In the PPR, wetlands, building sites, and wooded areas are preferred habitats (Fritzell 1978b); over half of the nocturnal locations reported by Greenwood (1982) were in wetlands. Examining habitat selection at the landscape level (i.e., selection of home range location), Pedlar et al. (1997) found that raccoons in Ontario frequented areas with extensive agricultural edge and wooded remnants in areas with extensive corn cover.

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Striped Skunk (*Mephitis mephitis*)

Distribution and Abundance

Striped skunks are found throughout the United States and southern Canada. They live in a variety of habitats including woods, prairies, and desert areas. They are abundant on agricultural landscapes where food and cover are ample. They also have adapted to urban areas, living under houses and garages. They are less common in unfragmented large forested areas where the food supply for skunks is low (Verts 1967).

Densities of skunks vary by geographic area. Reports of >5 skunks/km^2 are common throughout the geographic range of the striped skunk (Rosatte 1987), but in the PPR, densities of 0.5в1.0 skunk/km^2 are typical (Greenwood et al. 1985). Many factors contribute to variable geographic densities, including increased stress on vulnerable young animals by severe winter conditions in northern latitudes. But little is known about what factors limit local skunk populations. We do know that diseases, particularly rabies, can limit local populations (Greenwood et al. 1999).

Home Range

Spring skunk populations comprise loose aggregations of animals that commonly include an adult male with one or more adult females living in a portion of the male's home range (Sargeant et al. 1993). In mid to late spring, some adult males disperse long distances into new areas, sometimes >100 km away (Sargeant et al. 1982). Adult female skunks tend to remain in the same area for long periods.

The average home range (minimum convex polygon) of adult skunks in the PPR ranges from 1.2-2.5 km^2 for females and 2.9-3.1 km^2 for males (Bjorge et al. 1981, Rosatte and Gunson 1984, Greenwood et al. 1985). Skunk populations likely are not limited by spatial parameters, because female home ranges and core areas overlap extensively with conspecifics; skunks will concurrently forage in the same area (Greenwood et al. 1999).

Reproduction and Dispersal

Skunk populations are characterized by high recruitment rates and rapid turnover (Wade-Smith and Verts 1982). Males are polygamous, mating with several females. Both males and females are likely to breed their first year (Rosatte 1987) and nearly all females become pregnant (Greenwood and Sargeant 1994). Breeding occurs between mid-February and late April, the peak breeding period in Minnesota and North Dakota likely being around the end of February to early March. Mating occurs in the winter dens, which are often communal with male and females wintering together. However, males will travel from winter dens as soon as conditions allow, seeking other receptive females. Rutting activities of males may last as long as 36 days (Ernst 1965). Gestation ranges from 59 to 77 days (Verts 1967; delayed implantation may be involved [Nowak 1991]), with an inverse relationship between the date of mating and the length of gestation (Wade-Smith and Richmond 1978). Parturition usually occurs in early May. Mean litter size ranges from 5 to 9 kits (Rosatte 1987). Greenwood and Sargeant (1994) reported a mean of 7 kits/litter for 178 females collected in east-central North Dakota and west-central Minnesota.

Young skunks are nursed for 6B7 weeks and then are gradually introduced to foraging with their mother. Males do not participate in raising offspring. Most juvenile skunks will disperse from their natal areas during late-July through November (Bjorge et al. 1981).

Mortality

Major causes of mortality are human inflicted deaths (e.g., hunting, trapping, poisoning, and encounters with farm machinery and automobiles) and disease, including rabies (Rosatte 1987). Intraspecific aggression (adult males killing kits in rearing dens) and predation are less significant causes of mortality (Sargeant et al. 1982). Skunks are vulnerable to trapping and when high fur prices cause increased trapping activity, incidental capture of skunks during trapping for more valued species could significantly contribute to mortality. Epizootics such as rabies and distemper likely are among the greatest mortality factors. Several predators are known to kill skunks, including badgers (*Taxidea taxus*), coyotes, dogs (*C. familiaris*), red foxes, fishers (*Martes pennanti*), great-horned owls (*Bubo virginianus*), and golden eagles (*Aquila chrysaetos*). Bailey (1931) reported 57 skunk carcasses found beneath the nest of a great horned owl. Badgers killed kits prior to weaning in 23% of 40 skunk litters monitored in a North Dakota study (Sargeant et al. 1982). Sargeant et al. (1982) also reported cannibalism of skunk kits by adult male skunks.

Activity

Skunks are largely nocturnal and activity patterns of males and females are similar. Activity increases just before sunset and reaches a peak level within 1B2 hours, then gradually declines until sunrise. All skunks travel extensively each night, except on extremely cold nights and females just after parturition; some limited daytime movement may occur near rest sites (Greenwood et al. 1985).

Skunks are most active in summer and fall, particularly in September as they forage heavily to prepare for colder weather (Mutch and Aleksiuk 1977). In warm months, skunks move daily often to a different daytime retreat, which may be a simple aboveground bed. Females with kits, however, are restricted to the area of a natal den (Storm 1972, Larivière and Messier 1998). Some female skunks prepare and use just one rearing den, but many females use multiple dens. Female skunks may even display fidelity to natal den sites between years (Larivière and Messier 1998). During fall, activity levels and home range sizes steadily decrease (Sunquist 1974, Mutch and Aleksiuk 1977) and resting site use shifts from aboveground sites to more protective underground or enclosed sites (Storm 1972, Sunquist 1974). Adults start using winter dens by November and early December, but juveniles enter dens slightly later (Sunquist 1974). Communal denning of multiple females or females and a single male is common in winter dens (Verts 1967, Storm 1972). Skunks are not true hibernators and depend on stored fat, inactivity, warm underground dens, and slightly reduced body temperatures to survive (Mutch and Aleksiuk 1977). Typically, the winter denning period extends from December through March, although the actual length is dependent on the severity of winter (Sunquist 1974). During this period, skunks are largely inactive (Storm 1972) and may lose well over half of their body weight (Sunquist 1974). In late winter and early spring, including the mating period, activity outside of the den increases, and by May, the usual pattern of nocturnal activity has resumed (Sunquist 1974, Mutch and Aleksiuk 1977).

Food Habits

Although primarily insectivorous, skunks are opportunistic foragers. A variety of plant and animal foods are included in the diet, particularly when insects are not abundant. Focal areas of foraging correspond to the availability of invertebrate prey, and the diet reflects abundances of different prey types over time (Greenwood et al. 1999). Skunks are capable of identifying and capitalizing on pulses of invertebrate resources during the spring and summer (see Greenwood et al. 1999). They have an exceptional sense of smell and the capacity to form olfactory Asearch images@ (Nams 1997).

In North Dakota, Greenwood et al. (1999) found a greater percentage of plant food, including

large quantities of sunflower seeds, in early spring than in summer. As animal prey became more abundant, skunks focused on beetles, lepidoptera larvae, grasshoppers and crickets, and other insects. Skunks foraging in areas with abundant soil invertebrates used slow, deliberate movement, excavating shallow pits to locate prey (Greenwood et al. 1999). Bird eggs, primarily passerine and duck eggs, and voles, mice, and other mammals were important vertebrate sources of prey. Vickery et al. (1992) concluded that skunk depredation of eggs and nestlings occurred incidentally to foraging for insects.

Habitat Use

Skunks will use a variety of habitats. Greenwood et al. (1999) found skunks foraging most often in wet meadow and upland grassland, but they also used cropland, road rights-of-way, and tree plantings. Phillips et al. (2003) found skunks were most attracted to wetland edges for foraging areas of large continuous grassland and areas of highly fragmented grassland.

Edges of wetlands or waterways and farmsteads are common resting sites of skunks (Storm 1972, Larivière and Messier 1998) and man-made objects, including buildings, brush piles, and culverts are also used. Larivière and Messier (1998) found that areas of cropland were strongly avoided as resting sites, but Storm (1972) found skunks used resting sites in cropland in proportion to availability. Natal dens are often underground burrows that have been excavated by badgers, muskrats (*Ondatra zibethicus*), red foxes, or other skunks (Verts 1967, R. J. Greenwood and A. B. Sargeant, U.S. Geological Survey, Jamestown, ND, unpublished data). Habitats associated with farmsteads, such as under buildings or other man-made objects, are also inhabited as natal dens (Rosatte 1987, Larivière and Messier 1998; R. J. Greenwood and A. B. Sargeant, unpublished data). Because females restrict their activity in spring to areas near den sites, ducks nesting near den sites or in areas with a relatively high density of breeding female skunks are at risk to be encountered and depredated by foraging skunks.

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American Badger (*Taxidea taxus*)

Distribution and Abundance

Factors that influence badger abundance and distribution in the region are unclear; however variability in availability of grassland habitat due to agricultural practices as well as man-inflicted mortality (e.g., trapping, hunting) likely are important factors (Messick et al. 1981). Distribution of local populations might depend on the occurrence of fossorial prey (see Messick et al. 1981) and the level of human persecution. Badger populations in northern grasslands seem to be increasing since the onset of the Conservation Reserve Program (CRP; Greenwood and Sovada 1996, Sovada et al. 1999). As a species particularly suited to grassland habitat, the conversion of cultivated land to grassland under CRP benefited badgers by increasing the amount of suitable habitat in the landscape. Badgers tend to avoid cultivated areas (Messick and Hornocker 1981, Messick et al. 1981), therefore land use and habitat matrixes may be a factor in the distribution and abundance of this species, ultimately affecting depredations of nesting birds.

Little is known about the density of badger populations, except for two intensively studied populations located outside the PPR. Lindzey (1971) reported 0.4 badger/km^2 at a study along the Utah-Idaho border. Messick and Hornocker (1981) estimated that the Snake River Birds of Prey Natural Area and adjacent habitats in southwestern Idaho supported a density of 5 badgers/km^2; both areas had high densities of ground squirrels available as prey. Densities in the PPR are likely much lower.

Home Range

Badgers are solitary animals, but home ranges of resident badgers overlap (Messick and Hornocker 1981). Resident adults have established home ranges that expand and contract seasonally, but persist year after year. Many factors may influence home range size, including sex, region, and season. Juveniles do not have permanent home ranges; they move erratically and sometimes travel long distances as they disperse from their natal areas. Male badgers tend to use larger areas than females (Messick 1987, Goodrich and Buskirk 1998, Apps et al. 2002). There is much regional variation in home range size, likely related to local abundance of resources. Two separate studies of individual female badgers in central Minnesota (Cedar Creek Natural History Area) identified home ranges (minimum convex polygon [MCP]) of 8.5 km^2 (Sargeant and Warner 1972) and 17 km^2 (Lampe and Sovada 1981). Lindzey (1971) reported that badgers on the Utah-Idaho border had home ranges (MCP) that varied from 2.1 - 6.3 km^2. In southwestern Idaho, home ranges were <4 km^2 (MCP, Messick and Hornocker 1981) and in southeastern Wyoming, males and females had average MCP home ranges of 5.4 km^2 and 3.4 km^2, respectively (Goodrich and Buskirk 1998). In southeastern British Colombia where food resources are believed to be widely dispersed, badgers used large home ranges (males, 70 km^2 and females, 30 km^2, MCP; Apps et al. 2002). Preliminary analysis from North Dakota, indicated spring/summer home ranges of 29 badgers averaged 10 km^2 (95% MCP; M. Sovada unpublished data).

Home-range size is seasonally variable. Males have range expansions during the breeding season, females use only limited areas while lactating, and both sexes have smaller home ranges in the fall and winter (Messick and Hornocker 1981). Sargeant and Warner (1972) found that the range of a female badger in central Minnesota decreased from 7.61 km^2 in summer to 0.53 km^2 in autumn to only 0.02 km^2 in winter.

Reproduction and Dispersal

Badgers breed in July and August, but delay implantation of the blastocyst until between December and February (see Messick 1987). Young female badgers may breed when they are only 4 - 5 months old and give birth their first year, but more commonly they will not breed until they are 1 year old. Males, however, do not become sexually active until after their first year (Messick et al. 1981).

One to 4 young are born in March or April, but typically females give birth to only 2 young (Messick 1987). Juveniles remain with their mother for about 4 months before dispersing in late summer. Dispersal of young badgers is characterized by erratic movement and sometimes long distance travel (Messick 1987). In southwestern Idaho, a juvenile male dispersed >100 km (Messick et al. 1981).

Mortality

Humans cause most badger mortality, either intentionally or by vehicle collisions (Messick et al 1981). Although young badgers might occasionally fall victim to predators, such as golden eagles, coyotes, or dogs, adult badgers have few natural predators (Messick 1987). Little is known about the role of disease, parasitism, and starvation in badger populations, because mortality caused by these factors is not easily documented. Badgers' low reproductive rate results in slow recovery of depressed populations.

Activity

Badgers are largely nocturnal but occasionally are active during the day. Individuals gradually become less active during late fall and are inactive for prolonged periods during winter. During the fall, badgers accumulate a thick layer of fat that apparently is used during winter when food is less available and less accessible. An increase in hunting and caching of food in late fall coincides with badger weight gain, in preparation for periods of reduced activity in the winter (Michener 2000).

The activities of parous females differ from those of other resident badgers. Females use a shifting sequence of maternal dens as described by Lampe and Sovada (1981). Those authors reported the movements of a lactating female radiating from and within 200 ha of the maternal dens. In mid-to late May, the female foraged further from the dens and remained away from the young for periods of longer than 24 hours, a pattern that likely encouraged weaning. Lindzey (1978) observed similar activity of a female using 3 dens between 27 March and 8 June.

Food Habits

Badgers are opportunistic foragers and consume a wide variety of small mammals, birds, eggs, reptiles, amphibians, fishes, arthropods, and plant material (Messick and Hornocker 1981, Lampe 1982, Long and Killingley 1983, Sovada et al. 1999). They are adapted morphologically to digging and their diet, consisting largely of fossorial mammals, reflects this ability. Lampe (1976), observing badgers in large enclosures, found that badgers moved about 250 liters of soil for each pocket gopher (*Geomys bursarius*) captured and were successful in 73% of attempts.

Small mammals, primarily mice and voles but also pocket gophers and ground squirrels, were the most common food items in the diet of badgers in west-central Minnesota and southeastern North Dakota from April through July (Sovada et al. 1999). However, nearly one-third of 47 digestive tracks from adult badgers contained bird remains, including ducks, ducklings, and eggs. Insects and bird eggs were more common in summer than in spring, indicating the response to seasonally abundant prey (Sovada et al. 1999). Badgers are likely influenced by prey availability (Errington 1937, Snead and Hendrickson 1942

Messick and Hornocker 1981, Lampe 1982); thus, in areas with relatively densities of nesting ducks, we might expect increased proportions of ducks and their eggs in badger diets.

Most prey is eaten as soon as it is caught, but occasionally prey items are cached (Snead and Hendrickson 1942, Michener 2000). Michener (2000) observed that nightly prey handling by badgers could include combinations of caching, retrieval of previous caches, and consumption of fresh captures; caches made in October and November were revisited into December. In November in North Dakota, Umber (1994) found an entire deer carcass that had been buried by a badger.

Habitat Use

Habitat use generally reflects the fossorial habits of badgers. Badgers tend to avoid cultivated areas (Messick and Hornocker 1981) and are drawn to areas with an abundance of ground-dwelling prey and friable soils (Sargeant and Warner 1972). One of the most conspicuous signs of badger presence is the den, the badger's daytime refuge. Sites of overnight dens used by badgers change daily in summer, but old den holes are frequently used (Long and Killingley 1983, Sargeant and Warner 1972). Denning habits and activity levels change with the onset of cold weather. Extended use of a single den becomes more frequent as activity declines in the fall (Sargeant and Warner 1972), and badgers may stay underground for several days or weeks in winter (Messick and Hornocker 1981).

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American Mink (*Mustela vison*)

Distribution and Abundance

       Minks occur throughout most of North America. Although commonly associated with the permanent water of streams and lakes, they also are inhabitants of prairie wetlands. In a study of predator distribution and abundance in 33 areas throughout the PPR, Sargeant et al. (1993) found mink to be most common on study areas in west central Minnesota (Hawley, Hitterdal, and Lake Park), where they were approximately twice as abundant on other study areas in the PPR. Mink populations are closely tied to the wet/dry cycles of the PPR. Because minks rely on wetland areas for food and shelter, it is not surprising that drought reduces their reproductive success (Eberhardt 1974) and has catastrophic effects on mink populations (Sargeant et al. 1993). During drought, minks will disappear from much of the prairie, withdrawing to remaining water in permanent wetlands and river systems. However, minks can quickly repopulate the prairie through dispersal once water has returned and because of high reproductive capacity.

Home Range

       Prairie minks cover larger home ranges (Arnold and Fritzell 1987a) in contrast to the small linear home ranges of minks in riverine or coastal habitats (Dunstone and Birks 1983). The average home range (minimum convex polygon) of male mink from May through July in the prairie parkland of southwestern Manitoba was 6.2 km^2 (Arnold and Fritzell 1990).

Reproduction and Dispersal

       Minks are generally solitary, with males and females only associating briefly for mating. Mating occurs in March-early April and is regulated primarily by photoperiod (Enders 1952). During the breeding season, territorial males travel widely in search of females (Arnold and Fritzell 1987a). Minks can delay implantation, but late breeders might not delay. Parturition of young occurs from April to June, peaking in early May in Minnesota and North Dakota. Litters of 4 young are typical, although litters of 1 - 8 are possible (Eagle and Whitman 1987); litter size increases with female age. Females commonly split their litters between 2 dens. Eagle (1989) reported that by mid-August, juveniles from 4 litters moved independently of the female, but stayed within the maternal home range; 1 male kit moved independently as early as late July. This means that predator density on the maternal home range may increase from 1 female to as many as 8 minks during the period when waterfowl broods are vulnerable. Juveniles begin dispersing in approximately early September (Eagle and Whitman1987, Eagle 1989). Minks are sexually mature at 10 months (Enders 1952); females will reproduce their first year (Eagle and Whitman 1987).

Mortality

       Human-caused mortality, especially trapping, is the most significant cause of mortality for minks (Eagle and Whitman 1981). Predation by red foxes, coyotes, and great-horned owls (*Bubo virginianus*) and intraspecific aggression are other causes of mortality (Whitman 1981 Errington 1943).

Activity

As semiaquatic carnivores, foraging activities of minks are concentrated in the vicinity of wetlands, although prairie minks rely less on aquatic prey, such as fish and crayfish, than minks in other areas (Arnold and Fritzell 1987b, Melquist et al. 1981). Prairie minks are nocturnal and crepuscular (Arnold and Fritzell 1987a). In studies outside the PPR, minks were less strongly nocturnal (e.g., Whitman 1981, Dunstone and Birks 1983). In those areas, minks had a higher reliance on fish for food, necessitating high light conditions for underwater foraging (Sinclair et al. 1974).

Though active year-round, minks are less active in winter during low temperatures than in other times of the year (Marshall 1936). Food sources are limited during winter, especially if wetlands freeze to the bottom, forcing minks to rely entirely on terrestrial prey at this time.

Food Habits

Minks are opportunistic predators and their feeding habits reflect the availability of seasonally and annually variable food sources (Eberhardt 1973, Eberhardt and Sargeant 1977, Whitman 1981). Small mammals, including muskrats (*Ondatra zibethicus*), ground squirrels (*Spermophilus spp.*) as they emerge from hibernation, and voles (*Microtus spp.*), are the primary food source in the spring. Emphasis shifts to avian prey, including adults, hatchlings, and eggs of ducks, coots (*Fulica Americana*), grebes, and passerines, as birds become more abundant in the spring and summer. In parts of the PPR, birds make up the largest part of the mink's diet during times of limited mobility for birds (incubation, brood rearing, and molt; Arnold and Fritzell 1987b). However, Fleskes and Klaas (1993) reported that muskrats were the most common food item found at mink dens on a wildlife refuge in north-central Iowa.

In the prairies during the nesting season, overwater nesting birds, including diving ducks, coots, and grebes, are preyed upon heavily (Eberhardt and Sargeant 1977), although extensive predation on dabbling ducks was reported from a Manitoba study area that had little upland nesting habitats available (Arnold and Fritzell 1989). Marsh-nesting birds (including dabbling ducks) and their eggs comprised 91% of the total prey items found at the dens of male mink in Manitoba (Arnold and Fritzell 1989). Arnold and Fritzell (1989) estimated that a male minks would consume 3 adult ducks (mallard sized), 15 week-old ducklings, and 18 duck eggs (mallard sized) during a single season. Eberhardt and Sargeant (1977) observed sex-specific predation on male dabbling ducks and female diving ducks. Minks cache prey items for later consumption and excessive killing of more prey than can be handled has been reported.

Habitat Use

Minks depend on wetland habitats for foraging, including rivers, streams, lakes, and semipermanent and permanent wetlands. These habitats contain prey such as fish, crayfish, and muskrats. In the prairies, minks also occupy shallow prairie wetlands where their diet includes meadow voles, waterbirds, aquatic insects, and tiger salamanders (*Ambystoma tigrinum*) Eberhardt and Sargeant 1977, Arnold and Fritzell 1987b). A dependable food source seems crucial to habitats used by minks. Minks inhabiting the prairie are vulnerable to annual and seasonal fluctuations in water levels that affect food abundance and availability of den sites. Frequent and often widespread droughts, characteristic of PPR, greatly affect availability of prey, particularly in winter (e.g., winter freeze-out of shallow wetlands) and thus can lower the reproductive performance of minks (Eberhardt 1974). During droughts, minks often are forced to move to river systems that maintain water flow.

In the PPR, hundreds of wetlands typically fall within the home range of a mink, but foraging activity is focused on a small subset of these (between 10 and 30; Arnold and Fritzell 1990). Minks prefer semipermanent or permanent wetlands with irregular shorelines, high water levels, and large areas of open water (Arnold and Fritzell 1990).

Sites selected by minks for denning also are closely associated with water (Whitman 1981, Eberhardt and Sargeant 1977, Schladweiler and Storm 1969). Throughout their range, minks are known to make use of available shelter, including ground squirrel burrows, rock piles, brush piles, culverts,

dense stands of emergent vegetation, beaver (*Castor canadensis*) lodges, and natural crevices (Whitman 1981, Arnold and Fritzell 1989). In the PPR, muskrat burrows seem to be the most important den sites, to the extant that Eberhardt and Sargeant (1977) suggested that the availability of dens to minks was related to the suitability of the marsh for muskrats to create and maintain dens and to the amount of shoreline damage (i.e., den damage) caused by grazing livestock. Minks usually spend each day in a different den, except for females with litters that use only a few dens until their young are mobile. The average distance moved by a mink family between consecutive den sites was <0.5 km (Schladweiler and Storm 1969, Eberhardt and Sargeant 1977).

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**Long-tailed Weasel (*Mustela frenata*) and
Short-tailed Weasel (*M. erminea*)**

Distribution and Abundance

The long-tailed weasel has the largest distribution of any mustelid in the western hemisphere, occurring from the transition between aspen parkland and boreal forest in southern Canada throughout the United States and into Central and South America. The distribution of the short-tailed weasel is primarily north of the long-tailed weasel's distribution, covering Alaska and Canada and extending down into the western United States, the upper Great Lakes, and a portion of eastern United States (Higgins et al. 2000). Whereas the long-tailed weasel is found throughout the Prairie Pothole Region (PPR), the short-tailed weasel is more likely to be found in the aspen parkland, but it does occur in the prairie (Sargeant et al. 1993).

No estimates of weasel density are available for the PPR, but elsewhere density estimates for long-tailed weasels range from <1/km^2 (western Colorado) to >30/km^2 (forest in Pennsylvania and marsh in Ontario; Sheffield and Thomas 1997). Short-tailed weasel densities in North America range from 4в6/km^2 to 11/km^2 in preferred habitat (Fagerstone 1987). Sargeant et al. (1993) estimated that weasels were uniformly distributed and populations were low throughout the PPR. In areas of sympatry, short-tailed weasels tend to be more abundant than long-tailed weasels (Sheffield and Thomas 1997). Populations are at their lowest in the early spring after winter losses to predation and starvation have decreased the population and before spring reproduction.

Weasel populations appear to be regulated largely by prey abundance. Short-tailed weasels are more specialized in their foraging and likely are more easily affected by shortages of their primary prey than the long-tailed weasels, who typically can maintain population size while subsisting on alternate prey (King 1983, Sheffield and Thomas 1997). Still, weasel populations (both species) generally fluctuate and frequent local extinctions occur in response to prey numbers (Simms 1979, Fagerstone 1987, Sheffield and Thomas 1997). Population declines generally are caused not by increased mortality but by deficiencies in recruitment (King 1989). Spring rodent populations (during the parturition/young rearing period) might strongly affect the year's recruitment. Other factors that might influence variation in numbers include climate (snow depth and temperatures), habitat changes (e.g., flooding), and disease.

Home Range

Home ranges of long-tailed weasels vary from 10 - 24ha in areas of high prey abundance up to 80в160ha where prey resources are more limited (Quick 1944, 1951; DeVan 1982). Males have large home ranges that include the ranges of one or more females, but are exclusive of other males (Erlinge 1977, King 1983, Sheffield and Thomas 1997). Similarly, female home ranges are exclusive of other females. Females tend to avoid encountering the male on whose home range she lives (Erlinge 1977, Powell 1979). Size of male home ranges increase during breeding season (Sheffield and Thomas 1997). For both species, home range size varies according to habitat, prey abundance and the presence of other weasels (King 1983, Fagerstone 1987). It seems that weasels will retain as large a territory as possible (Fagerstone 1987). Population structure is unstable, as there is rapid turnover of resident adults (King 1983, Sheffield and Thomas 1997).

Reproduction and Dispersal

Males and females live separately for most of the year, except during a brief mating period (King 1983, Sheffield and Thomas 1997). Males are polygynous and start seeking receptive females from early April through mid-August (Fagerstone 1987). Sheffield and Thomas (1997) suggested that a high incidence of weasels killed by vehicles in Washington indicated that males exhibit transient behavior during breeding season, roaming large areas in search of mates. Following mating, the ova develop for 8 days, and then delay further development until the following spring. After this period of delayed implantation, gestation lasts 23B27 days and young are born in April or early May (Wright 1947).

Females give birth to 1 litter each year, typically to 4B5 young, but up to 9 are possible in long-tailed weasels (Sheffield and Thomas 1997), and 4B8, with up to 13 possible in short-tailed weasel (King 1983). Reproductive success is strongly influenced by food supplies in spring (King 1989). Females are responsible for raising the young. Instances of males delivering food to a rearing den are most likely attempts by the male to gain access to adult females and female offspring, because adult females mate soon after parturition and young females breed in their first year at 3B4 months of age (King 1989). Males are sexually immature in their first summer and do not mate until the following breeding season (Sheffield and Thomas 1997).

The young are able to eat solid food brought to the den within their first 6 weeks, although lactation continues for 7B12 weeks. Juveniles emerge from the den at 6B8 weeks. Playing outside the den may progress to hunting with the female during the last stages of the weaning period (Fagerstone 1987). Juveniles typically disperse in mid-summer into autumn (Erlinge 1977, Fagerstone 1987). Females usually do not move far from their natal area, generally less than 5-6 km, but males disperse much greater distances, with movements >20 km not unusual (King 1989).

Mortality

Mortalities may be caused by predation from foxes, raptors, domestic dogs, cats (*Felis catus*), and coyotes. Long-tailed weasels may kill short-tailed weasels. Lathum (1952) provided indirect evidence that predation can be important to weasel populations. He documented declining numbers of weasels trapped as harvest of red foxes and gray foxes (*Urocyon cinereoargenteus*) increased and that weasel carcasses were frequently found at fox dens. Mortality from intentional and incidental fur trapping is probably of minor consequence. Other causes of mortality include starvation over winter, vehicle collisions, and diseases, although the incidence of disease in weasels is poorly known.

Activity

Weasels are active year round. Their elongated shape, short fur, and inability to curl into a sphere while resting cause weasels to lose heat rapidly, thus weasels have unusually high metabolic demands. Captive long-tailed weasels consume 17B33% of their body weight per day (Sheffield and Thomas 1997) and a female short-tailed weasel consumed 12B27% (Fagerstone 1987). In general, weasels are active for short periods alternating with rest periods and may be active at any time throughout the day (King 1983). The exact daily activity pattern is unknown and may differ between populations.

Weasels rely primarily on their acute olfaction and hearing to locate prey. They are superbly adapted to pursuing and killing fossorial rodents in their burrows, but they also hunt above ground, in trees, and under the snow (King 1983, Sheffield and Thomas 1997). Distance traveled on a single foraging trip average 1.3 km, but may be up to 8 km; duration of foraging and distance traveled decreased when prey is abundant (King 1983).

Surplus prey is cached, typically underground, and usually in or associated with dens. However, aboveground caching (in trees and shrubs) of winter kills has been observed, possibly as a means to reduce decomposition rate (Weeks 1993). Caches are important stores of energy. Weasels do not store

up fat reserves, since they must be able to travel through tunnels to hunt (King 1983); therefore, they kill whenever given the opportunity and cache what is not immediately required (King 1983).

Food Habits

 Of the mammalian nest predators of the PPR, weasels are perhaps the most specialized in their prey requirements. Although occupying slightly different niches, both weasel species are carnivores with diets composed primarily of small mammals. Due to pronounced sexual dimorphism, males generally take larger prey than females.

 Long-tailed weasels are the largest and most generalist in food habits of the 3 North American weasels species; they take a greater variety of prey than short-tailed weasels, including cricetids, sciurids, leporids, and birds. Small rodents are the main prey, but their diet also includes medium-sized rodents such as pocket gophers, ground squirrels, young prairie dogs, and rabbits. Young and adult ground-nesting birds and eggs may be eaten if encountered. The diet varies seasonally in response to temporal shifts in prey abundance (Sheffield and Thomas 1997). The short-tailed weasel has a more specialized diet, consisting primarily of small mammals, especially voles, but also including some medium-sized prey such as rabbits, and eggs and nestlings (King 1983).

 Both long-tailed weasels and short-tailed weasels are known predators of duck eggs (Teer 1964, Crabtree and Wolf 1988, Fleskes 1988). In a study of nest predation by weasels in northern Iowa, 263 upland duck nests were depredated and of those, 38 had eggs taken by weasels; 27 of the 38 nest failures were attributed solely to weasel depredation (Fleskes 1988). Eggs may be removed by weasels from a nest over several days. At Delta Marsh, Manitoba, of 59 nests with known histories, 23 were destroyed by predators, of which 3 were attributed to predation by long-tailed weasels (Teer 1964).

Habitat Use

 In general, a suitable prey base seems to be the most critical habitat requirement for weasels. Cultivated land, open woodland, or other areas without sufficient cover for prey or weasels probably are avoided. The long-tailed weasel uses waterways in daily activity and perhaps as avenues for dispersal, and it seems that long-tailed weasels are partially restricted to the vicinity of freestanding water (Gamble 1980). Within the home range, areas of high prey density are visited more than other areas (King 1989). When prey is not abundant, weasels will increase distances traveled for foraging.

 Weasels do not burrow or dig their own dens (King 1989). They typically commandeer the burrow systems of their prey, often of a larger rodent or rabbit. Nests are improved by lining them with the fur of prey. Small dens, brush piles, rock piles, or hollow trees may also serve as nest sites (King 1983; Sheffield and Thomas 1997). Weasels are excellent climbers and may use trees for escape, prey capture, and as rest sites (Nams and Beare 1982). They are also excellent swimmers.

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Franklin's Ground Squirrel (*Spermophilus franklinii*)

Distribution and Abundance

Populations of Franklin's ground squirrels are discontinuous throughout their geographic range. Isolated populations typically occur in areas of dense upland cover or near the interface of timber and grassland, but seldom in habits with sparse or short vegetation (Sowls 1948, Erlien and Tester 1984, Choromanski-Norris et al. 1989). Little is known about the distribution and abundance of this species prior to human settlement. Distribution can be very patchy; it is not unusual for Franklin's ground squirrels to be present on a particular Waterfowl Production Area (WPA), but absent from other nearby WPAs (M. Sovada, personal observation). Nothing is known about how this rodent pioneers into new areas.

Population estimates are extremely variable throughout their range. Two studies at Delta Marsh in Manitoba reported densities of 10ʙ12 squirrels/ha (Sowls 1948) and 4ʙ6 squirrels/ha (Lynch 1972). In Alberta, Murie (1973) reported densities of 1ʙ3 adults/ha and Haggerty (1968) reported a density of <2 adults/ha at Itasca Park, Minnesota. Populations of Franklin's ground squirrels are subject to extreme fluctuations (Sowls 1948) and Erlien and Tester (1984) suggested they might be on a 10-year cycle, but no mechanism was identified.

Home Range

Adult Franklin's ground squirrels tend to be asocial, unlike other species of ground squirrel. However, numerous individuals with overlapping home ranges may inhabit the same area (Choromanski-Norris 1983). In a study on a WPA in North Dakota, annual home ranges of males were larger (0 ' 24.6 ha, range 5.4-52.9 ha) than those of females (0 ' 8.7 ha, range 2.5-22.7 ha). Bi-weekly home ranges were much smaller than annual home ranges of both sexes (males, 0 ' 7.2; females, 0 ' 2.7 ha), indicating that only a portion of the annual home range was used during shorter intervals (Choromanski-Norris 1982). Furthermore, these spatial shifts in activity (greater in males than females) indicate an ability to recognize and exploit temporary concentrations of food (Choromanski-Norris et al. 1989).

Reproduction and Dispersal

Typically females emerge in early May, 2 weeks after males, and breeding occurs soon afterward. A pair may briefly occupy a burrow system, but after mating the male departs. In late May or June, after a 28-day gestation period, females give birth to a litter of 7 - 9 young (Sowls 1948, Iverson and Turner 1972). Young are weaned by early July. There is no information available on dispersal of young or adult Franklin's ground squirrels in the region.

Mortality

        Avian and mammalian predators, including hawk, weasel, mink, red fox, coyote, American badger, and striped skunk, may take Franklin's ground squirrels, but Sowls (1948) reported that it was unlikely that predation is a principle cause of mortality in a population. However, Choromanski-Norris et al. (1989) reported predators, primarily red foxes, killed 15 of 49 radio-marked ground squirrels. A substantial proportion of mortality likely occurs during hibernation; in an Alberta population, emerging squirrels had lost 44.2% of their body weight over winter (Murie 1973). Minimum over-winter survival rates were from 20 - 60% (Iverson and Turner 1972, Murie 1973).

Activity

        Franklin's ground squirrels are active for only 5 - 6 months a year. Local environmental conditions are thought to influence timing of seasonal events (e.g., emergence from hibernation), since the timing of events in populations at the same latitude might differ by 2 - 3 weeks (Murie 1973). Spring emergence from hibernation is most likely a response to soil temperature cues. In central North Dakota, males emerge in mid-April, 2 weeks before the females, and breeding occurs soon afterward (Choromanski-Norris et al. 1986). Although there may be brief periods of weight loss associated with reproductive activities in both males and females, weight gain is important during summer and may be particularly intense during the month prior to dormancy (Choromanski-Norris et al. 1989). Adult males begin dormancy in early August, followed about 3 weeks later by females. Most adults are no longer active by September, but juvenile squirrels may remain active aboveground until October, perhaps to allow greater weight gain (Iverson and Turner 1972).

        Franklin's ground squirrels are strictly diurnal. They are typically active from 1-2 hours after sunrise until 1-2 hours before sunset (Choromanski-Norris et al. 1989), although low temperatures, rain, or wind may inhibit aboveground activity (Sowls 1948, Choromanski-Norris et al. 1989).

Food Habits

        Franklin's ground squirrels, similar to the thirteen-lined ground squirrel, tend to be more omnivorous than other ground squirrels. Plants are their primary source of food, but small rodents, carrion, insects, and eggs (including duck eggs) are also included in the diet (Bailey 1926, Sowls 1948, Sargeant et al. 1987). Animal matter makes up about one-third of their diet (Bailey 1926). Evidence suggests that Franklin's ground squirrels can be significant predators of bird nests. Sowls (1948) documented severe depredation of upland duck nests by Franklin's ground squirrels at Delta Marsh, Manitoba, where ground squirrels were responsible for destruction of 19% of the duck nests accessible to them. Several waterfowl nesting studies conducted by Northern Prairie Wildlife Research Center staff have identified Franklin's ground squirrels as predators of eggs and nestlings of ducks and other birds.

Habitat Use

        Favorite habitats of this rodent are tall, dense cover of coarse grasses, forbs, and shrubs. They are typical inhabitants of parkland and shrubland areas and do not occupy wide stretches of prairie unless there is ample dense cover for concealment. Franklin's ground squirrels are adept at climbing trees and swimming, although these skills are generally not used while foraging. Choromanski-Norris et al. (1989) studied Franklin's ground squirrels on a Waterfowl Production Area (WPA) in North Dakota and found that squirrels spent most of their time in dense nesting cover, with only occasional foraging on adjacent cropland. The most heavily used grasslands were fields in which vegetation and soil had been undisturbed for the longest period. Differences in vegetation height, density, or litter depth did not explain differences in use among grassland types (native prairie, different ages of dense nesting cover, wetland edges, occasionally mowed or burned fields). Mowed and burned habitat was avoided until the vegetation grew back to about 30 cm. Choromanski-Norris et al. (1989) suggested that squirrel

distribution appeared to be related not only to cover type, but also to the distribution of abandoned burrows of northern pocket gophers (*Thomomys talpoides*), which the squirrels inhabited.

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