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Biological aspects of wolf recolonization in Utah

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4. Biological Aspects of Wolf Recolonization in Utah

Wolves have been one of the most scientifically examined of all wildlife species (Mech, 1995b). Many studies have focused on the effects of wolf reintroductions and recolonization. In this section, we address how wolves may naturally disperse into Utah, highlight areas identified in our habitat model as constituting the most favorable wolf habitat in Utah, estimate potential wolf populations in Utah, and describe what is currently known about the influence of wolves on an ecosystem.

4.1. Natural Recolonization

The wide-ranging dispersal ability of wolves has been well documented (e.g., Gese and Mech 1991). Dispersing wolves can travel hundreds of kilometers in search of potential mates (Mech [1970] 1981). In fact, one female wolf from Glacier National Park, Montana, was killed more than 800 kilometers north of its natal pack's territory (Ream et al., 1991). When released from anthropogenic hunting pressure, wolves can quickly recolonize former habitat (Hayes and Harestad, 2000). For example, when the eastern timber wolf in Minnesota was listed as a federal endangered species in 1974, the taking of wolves was prohibited, and wolves quickly expanded their range both within the state of Minnesota and as well as the neighboring states of Wisconsin and Michigan, where they had been extirpated (Fuller et al., 1992). Additionally, during the 1980s, wolves dispersing from Canada recolonized northwestern Montana. Wolves reintroduced to Yellowstone National Park (Yellowstone) are dispersing and establishing packs outside of the park (Smith et al., 2000). Several lone Yellowstone wolves have traveled relatively far outside of the Greater Yellowstone Ecosystem (GYE) (Figure 3). Furthermore, an unconfirmed sighting of a possible lone wolf in the Mount Naomi Wilderness in the Bear River Range of northern Utah occurred in 2000 (Associated Press 2000), and a wolf was suspected of killing sheep about 40 kilometers southeast of Logan in July, 2002 (Israelsen, 2002).

If wolves in the northern Rockies are allowed to expand their population, dispersal outside of the GYE will be inevitable. Some wolves will travel south toward Utah. Geographic Information Systems (GIS) analysis has shown high connectivity of intact habitat between the GYE and both the Bear River Range of northern Utah and Flaming Gorge National Recreation Area (Jones and Tingey, 2001). At present, these corridors are the most likely avenues of dispersal to Utah. However, additional reintroductions are being advocated in both the Grand Canyon Ecoregion (P. Sneed, personal communication; see also Sneed, 2000) and in the southern Rockies of Colorado and New Mexico (Phillips et al., 2000). Canyon National Parks and the Dixie National Forest, as well as from the east via the Book Cliffs or La Sal Mountains, all of which constitute favorable habitat according to our habitat model (see Section 4.2).

Despite these avenues for possible dispersal, a number of human factors may prevent wolves from establishing a viable population in Utah. Dispersing wolves typically suffer
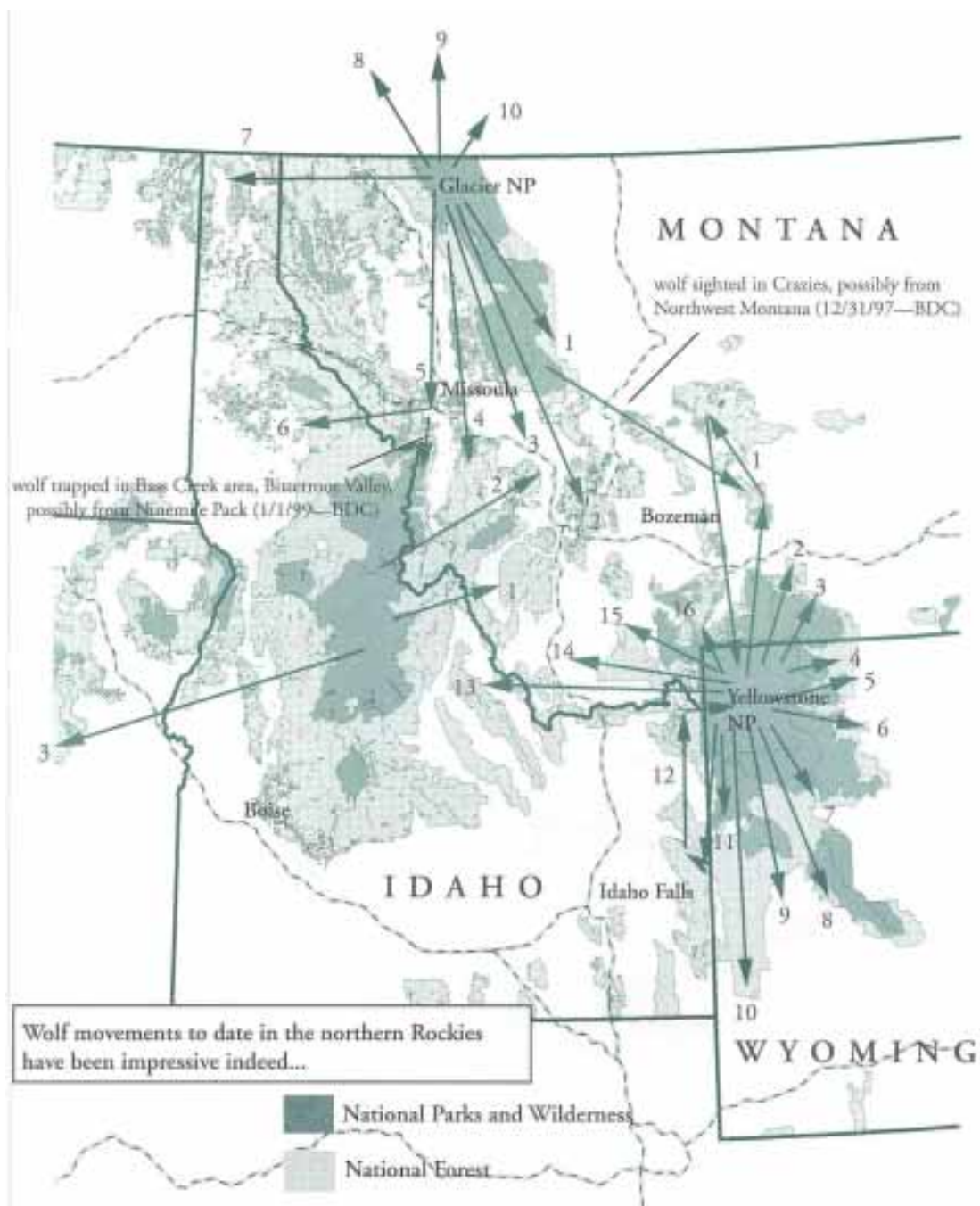
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Figure 3. Wolf movements in the northern Rockies, 1986 to early 1999 (Gaillard et al., 1999; reprinted with permission). Each arrow depicts an individual wolf's approximate dispersal route.

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higher rates of mortality than resident wolves (Peterson et al., 1984). Many wolves that disperse south from the Idaho recovery area are presently being relocated or euthanized by the U.S. Fish and Wildlife Service, largely because of conflicts with livestock. However, wolves dispersing into Oregon will, in general, no longer be relocated unless conflicts occur (E. Bangs, USFWS, personal communication). Other barriers to wolves dispersing from the GYE include poaching, automobile collisions, and relatively narrow habitat corridors. Since reintroduction in Yellowstone, more than 30 human-caused mortalities of wolves have occurred outside of the Park (Phillips and Smith, 1997; D. Smith 1998; D. Smith et al., 1999b, 2000). Additionally, the reintroductions being advocated for the Grand Canyon Ecoregion and southern Rockies of Colorado and New Mexico may never occur.

As a consequence of these factors, it might take many years for even a single resident pack to become established in Utah. A single pack would be unlikely to survive long enough to found a truly viable population. Accordingly, a self-sustaining population of wolves might not be possible in Utah without human intervention. If Utah residents and policy makers decide that a viable population of wolves within Utah in the next few decades is desirable, reintroduction may be necessary. In either case, however, it will be important to identify likely wolf habitat across the state to facilitate the implementation of proactive measures designed to reduce conflicts with humans and livestock.

Which subspecies of wolf historically inhabited Utah is a matter of debate. North American wolves were once categorized as 24 separate subspecies (Hall and Kelson, 1959). Nowak (1995), however, identified only five subspecies in North America, with *Canis lupus nubilus* occupying most of the western United States. Using genetic evidence, Forbes and Boyd (1996) suggest that distinct subspecies of wolves may not exist, but rather that genetic variation is continuous with distance. *Canis lupus occidentalis* from British Columbia and Alberta were reintroduced into Yellowstone because of similar habitat and prey base between the three areas. Any wolves dispersing to Utah from the north would be this same subspecies. For this reason, if wolf reintroduction were to be implemented in northern or central Utah, we would recommend using either *C. l. occidentalis* or *C. l. nubilis.* However, the wolves that originally inhabited southern Utah may have been more closely related to the Mexican wolf, *C. l. baileyi.* In addition, any further reintroductions in Arizona will almost certainly utilize Mexican wolves. For this reason, a recovering wolf population in Utah might consist of *C. l. occidentalis* or *C. l. nubilis* in northern Utah with genetic gradation to *C. l. baileyi* in southern Utah.

4.2. Assessment of Potential Wolf Habitat in Utah
We have identified areas in Utah where dispersing wolves are most likely to colonize, as well as those that are most suitable for the establishment of self-sustaining wolf populations. In addition, we have derived estimates of the number of wolves that each area could support over the long term. Although we have used the best data available for this analysis, the results are preliminary, and should be viewed as such. For example, we have not explicitly included geographic proximity to possible migration corridors into Utah as a consideration, although such proximity could be an important determinant, at

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least in the initial stages of a recolonization event. Our focus was directed more toward identifying all areas of potential wolf habitat. We also recognize that some areas with the potential to support wolves may not be considered appropriate for other reasons, such as the presence of high densities of livestock.

Habitat selection by wolves is complex and not yet completely understood. Fundamentally, wolves tend to locate in areas that have both an adequate prey base and a minimum of human interference (Mech, 1995a; Mladenoff et al., 1995). We have used coarse-scale population estimates of ungulates in combination with likely distributions among habitat types, both obtained from the Utah Division of Wildlife Resources (DWR), to identify areas in Utah that support adequate prey populations, and are therefore capable of supporting wolves. It should be noted, however, that these population estimates are very approximate because extensive field data are not available. Wolves are ecologically adaptable and have shown a capacity to persist in close proximity to human populations, given an adequate prey base (Boitani, 1982; Mech, 1995a; Blanco, 2000). However, because of the very high percentage of adult wolf mortality that is human associated, primarily the result of intentional and unintentional shootings and highway deaths, viable populations should be more likely to persist in relatively isolated areas (Thiel, 1985; Fuller, 1989; Thurber et al., 1994; Pletscher et al., 1997). Road density is a commonly used surrogate for probable levels of human-associated wolf mortality (e.g., Mladenoff et al., 1995) and has been shown to be a robust predictor of wolf colonization in the Great Lakes region (Mladenoff and Sickley, 1998). For this reason, we have used low road density as the other primary criterion in determining the favorability of potential wolf habitat.

In addition to low road density and adequate prey, several other factors are important in delineating suitable wolf habitat. Wolves require year-round access to fresh water, especially during denning (Mech [1970] 1981); however, few data are available regarding how access to water may affect pack territory size or location. Accordingly, we used proximity to perennial streams and lakes as a criterion. In addition, wolves tend to avoid high elevations and rugged terrain (Carroll et al., 2001), presumably because of the difficulty of catching prey on a year-round basis, as large ungulates tend to migrate to lower elevations in winter. Although many other factors can affect wolf habitat selection, we have selected these five (adequate prey, low road density, year-round access to water, appropriate elevation, and appropriate topography) as critical to a preliminary designation of favorable habitat. It is important to keep in mind that although these criteria are generally accepted as applicable, it is not entirely clear whether the unique topography and climate of Utah may interact to alter wolf habitat selection in unpredictable ways.

We have used a Geographic Information Systems (GIS)-based approach to construct a "static" habitat suitability model for Utah. The model is static in the sense that population dynamics were not considered in evaluating habitat. Areas with the biological potential to support wolves were identified using this model. Essentially, we generated GIS coverages for each habitat attribute, and generated a habitat "score" ranging from least favorable to most favorable for each point on the coverage, depending on the value of the habitat attribute at that point. The exception was the initial step, in which road density

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was used in a linear regression equation to predict probability of wolf occupancy, using the method developed by Mladenoff et al. (1995). Areas with a predicted probability of occupancy of less than 50% were not considered further. For this reason, our estimate of the total area of favorable wolf habitat should be considered conservative, and is probably an underestimate. The habitat scores were assigned using information obtained from both the scientific literature and from consultations with wolf biologists. A detailed enumeration of how the scores were developed is available upon request. Once areas of favorable habitat had been identified using this model, we used two methods to estimate the number of wolves that the best-quality habitat would likely support, and applied simple but robust population modeling techniques to estimate the long-term viability of wolf populations in each area.

A map of the resulting habitat model is shown in Figure 4. It can be seen that most of forested, mountainous Utah, an area of over 36,000 km^2, has the potential for wolf recolonization. However, because of high road densities, our model scored many parts of these areas as marginal wolf habitat, resulting in a substantial degree of fragmentation. Despite this fragmentation, a number of relatively large, contiguous areas of high-quality habitat can be identified from this map. The largest of these areas, approximately 5,900 km^2, is in the Book Cliffs region, extending eastward over much of the Tavaputs Plateau. A relatively large proportion of this potential habitat is on the Uintah and Ouray Indian Reservation, with the rest being primarily under the jurisdiction of the Bureau of Land Management (BLM). Other areas with a high potential for supporting wolves include (1) eastern Daggett County along the Green River (~350 km^2), most of which is again administered by the BLM; (2) the area northwest of Starvation Reservoir in the lower elevations of the Uinta Mountains (~330 km^2), which falls partly in Ashley National Forest and partly on the Uintah and Ouray Indian Reservation; (3) an area near Boulder (~1,880 km^2) that includes Boulder Mountain (Dixie National Forest) and parts of Grand Staircase/Escalante National Monument and Capitol Reef National Park; (4) an area southwest of Ferron (~1,160 km^2) that is split between the Manti-La Sal and Fishlake National Forests; and (5) the Kolob Terrace (~350 km^2), south of Cedar city, partly in the Dixie National Forest and partly in Zion National Park.

Although we focus on these areas, it should be noted that a number of other areas have the potential to support wolves. One of the weaknesses of this type of approach is that we were unable to include a measure of actual road use in our road-density calculation. Clearly, not all roads will have similar effects on wolf mortality, and hence habitat that appears to be highly fragmented in our model may in fact be relatively contiguous. For that reason, we suspect that the habitat we have identified may be an underestimate. On the other hand, land ownership and land use are certain to have a dramatic impact on whether habitat identified using this model is in fact capable of supporting wolves. We have chosen to focus on a relatively small number of areas that are largely under public ownership. However, some corridors between the core areas overlap private land where potential conflict would be higher. In addition, livestock grazing occurs in or near many of these areas, which also raises the potential for conflicts. These issues will need to be
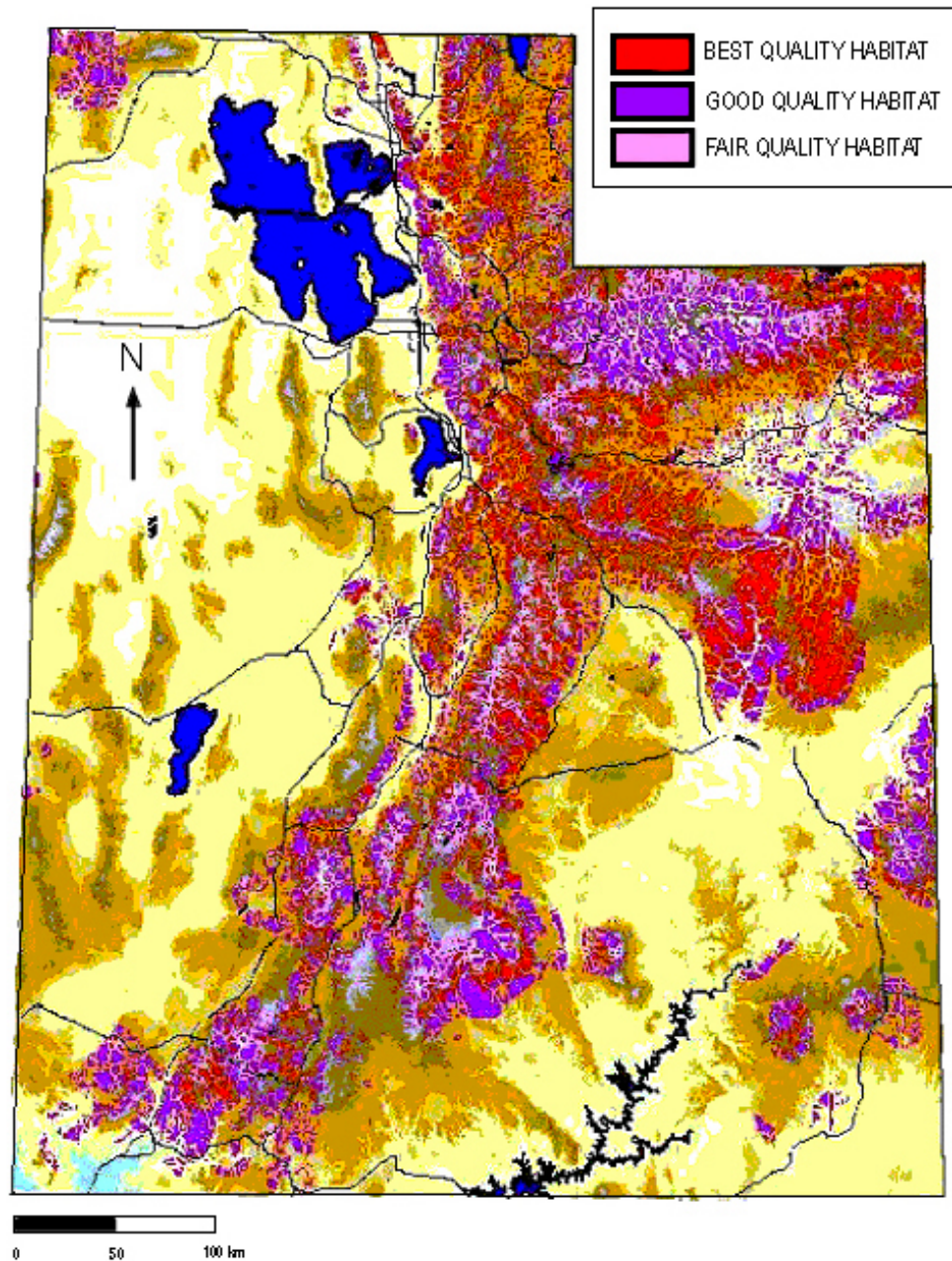
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 Figure 4. Potential wolf habitat in Utah overlaid on a Digital Elevation Model (DEM). Areas that scored as suitable habitat are shown in pink, purple, and red. The DEM is shaded from light blue (lowest elevation) to lavender (highest elevation). Major roads are shown in black.

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considered carefully. Our goal was simply to identify those areas of Utah that were likely to be the most favorable for wolves in a biological sense.

4.3. Estimates of Potential Wolf Populations in Utah
To estimate the number of wolves that Utah might support, we used two methods. The first, developed by Fuller (1989), relates ungulate density, normalized to "deer-equivalents," to a predicted overall wolf density in an area. Using this method, in combination with the Utah DWR's coarse-scale estimates of ungulate populations, we calculated likely wolf densities. We then used these estimated densities to calculate the total wolf population that could be supported, both in each area of contiguous high-quality habitat, as well as statewide. The results of this analysis are given in Table 1. The statewide estimates were derived by assuming that approximately 2/3 of the 36,000 km^2 of favorable wolf habitat would be occupied. This seems very unlikely, even under the most favorable political and social conditions, and therefore a calculation based on this assumption should provide an upper limit for total wolf numbers in the state. Using this assumption, we calculated that Utah could, in theory, support approximately 700 wolves (see Table 1) distributed throughout the state. We applied the same method to the six areas of favorable habitat identified above, which we refer to as "core" habitat areas. The number of wolves each area might support varies from 6 (Green River and Kolob Terrace) to more than 100 (Book Cliffs). Taken together, we estimate that the core habitat could, in theory, support just over 200 wolves.

An alternative method uses ungulate densities to estimate average pack-territory size (Fuller, 1989). Wolf populations can then be calculated on the basis of this estimate, in combination with estimates of average late-winter pack size, percent of wolves not belonging to any pack, and proportion of habitat in interstitial territory, using a relationship developed by Fuller et al. (1992). These parameters are difficult to estimate accurately, however. Average pack size, in particular, has a large influence on the population estimate, and average pack sizes have been reported to vary from 5 to 12 animals (see e.g. Fuller, 1995). Accordingly, this calculation may be more uncertain. Nevertheless, estimates using this method were generally similar to those found using the previous method. For simplicity, we refer only to population estimates derived using Fuller's (1989) method.

In the previous analysis, we calculated the theoretical wolf population that could be sustained by a given prey density. However, under any recolonization scenario, including active reintroduction, the initial population size will be small. In an attempt to determine the likely fate of an initially small wolf population in Utah, we used population-modeling techniques. We used the VORTEX population-viability analysis software package (Lacy, 1994), as well as a simple stochastic population model designed by one of the authors (T. Simmons, 2001, unpublished data) to examine the fate of a small colonizing wolf population in the large high-quality habitat patch identified in the Book Cliffs (the details of these analyses are available upon request). VORTEX follows the fate of each individual in the population, but is not designed to model species with complex social

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Table 1. Estimates of Potential Wolf Populations in Utah

Core Habitat Area	Estimated Number of Wolves Supported
Book Cliffs	102
Green River	6
Southern Uinta Mountains	7
Boulder Mountain	43
Fishlake/Manti-La Sal	50
Kolob Terrace	6
Total for Core Habitat Areas	**214**
Statewide (Core + Peripheral) Total	**711**

behaviors such as gray wolves. Our model attempted to take the unique reproductive behavior of wolves into account, but dealt with the population as a whole. Both approaches led to essentially the same conclusion: In the absence of immigration (i.e., a constant supply of dispersing wolves from outside the area) or a concerted effort to minimize human caused mortality, a small (10-15 animals) colonizing population would increase only very slowly at best, and would be subject to a high risk of local extinction. Higher starting populations (15-30 animals) gave similar results, although the risk of local extinction decreased. The modeling results suggest that the wolf population in Utah is unlikely to reach significant numbers in the absence of human intervention, although these types of theoretical approaches are highly uncertain (Fritts and Carbyn, 1995).

Because we were interested in assessing the likely impacts of wolves on, for example, livestock in Utah, we needed to select a wolf population level or range of levels to conduct that assessment. Given the inherent uncertainty in forecasting population growth, we felt it would be prudent to select a number that was higher than we believed was likely to occur, at least absent a concerted recovery effort by the state. Because the highest-quality, relatively contiguous habitat patches are predicted to support a maximum of 214 wolves (Table 1), 200 would seem to be a reasonable number for assessing the maximum potential economic and social impacts of wolves in Utah. For these reasons, we have assumed a wolf population of 200 for all further analyses.

4.4. The Effects of Wolf Recolonization on Ecosystems
Wolf restoration efforts throughout the United States are increasing significantly our knowledge of the ecological functions of wolves and their effects on ecosystems. Wolves are a top-level predator whose presence is an indicator of an ecosystem's integrity. Although the literature suggests that recolonizing wolves will probably have a small effect on the dynamics of Utah's ungulate populations, they may exhibit a greater influence through changes in ungulate behavior and cascading effects. It has been more than seven years since wolves were reintroduced into Yellowstone National Park. Although long-term data are not yet available, wolves seem to be demonstrating significant effects throughout that ecosystem. The results of this natural experiment can help us gauge the potential effects of wolves on Utah's ecosystems and will be cited

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frequently in this section. In this section we review current literature regarding how wolves may affect ungulate populations, ungulate behavior, and other predators and scavengers. In addition, we estimate the magnitude of the impact of wolf predation on ungulate populations in Utah.

Ungulate Populations

Much concern has been expressed over the impact of wolves on deer and elk populations in Utah (UT DWR 2001a; Peay, 2001a, 2001b). The degree to which wolves may regulate or limit prey populations remains controversial (Gese and Knowlton, 2001). This debate stems from the difficulty of large-scale, long-term studies, lack of adequate replication or controls, and differing interpretations of the same data. Despite these constraints, a number of studies have described the influence of wolf predation on wild, native ungulate populations (reviewed by Bennett, 1994 and Ballard et al., 2001). Because limited research has addressed the interaction between wolves and mule deer, or been conducted in habitat similar to that found in Utah, we have relied on studies from other areas (the Great Lakes, Canada, and Alaska) that deal primarily with other prey species (white-tailed deer, elk, Dall sheep, caribou, bison, and moose).

Typically, wolves do not appear to dramatically reduce prey populations (e.g., Van Ballenberghe, 1985; Fuller, 1990). Rather, wolf predation appears to generally dampen fluctuations in prey numbers (e.g., Leopold, [1933] 1986; Pimlott, 1967; Carbyn, 1983). One reason for this may be that wolves generally seize upon the most vulnerable prey (e.g., young, old, sick, and injured), which are the easiest animals to catch and kill (e.g., Murie, 1944; Fuller and Keith, 1980; Kunkel and Pletscher, 1999). This is quite different from human hunting, in which different selection criteria operate. For example, since 1995, the average age of wolf kills in Yellowstone and the National Elk Refuge in Wyoming has been 14 and 19 years, respectively, whereas hunter kills averaged 6 years of age in both areas (D. Smith, 2001; B. Smith and Berger, 2001). Furthermore, a study in Idaho demonstrated that hunter-harvested elk are generally in much better physical condition than those killed by wolves (Power, 2001). Accordingly, wolves may actually improve the health of an ungulate herd by removing either diseased or disease-prone animals that could act as vectors to an entire herd (Mech, 1966; Carbyn et al., 1993). Finally, predators, by preying on smaller, weaker individuals, may select for larger, healthier ungulates over the long term (e.g., Kie et al., 1979; Knowlton and Stoddart, 1992).

In general, predation can be defined as either compensatory mortality, in which an additional form of mortality reduces other causes, or as additive mortality, in which predation increases the overall mortality rate (Bartmann et al., 1992). For example, wolves killing a winter-weakened ungulate would be defined as compensatory predation if the death of that animal from other causes was inevitable, as is often the case. On the other hand, predation by wolves and other large predators has, at least in some cases, been shown to be additive. These studies, most of which were conducted in Alaska and Canada, suggest that predation by wolves in combination with other predators, including humans, can limit prey populations (reviewed in Kay, 1996; Kunkel and Pletscher, 1999).

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However, such limitation may occur primarily when prey populations have been severely reduced by other factors. These factors could include hunting, poor habitat, extreme weather, food availability, changes in the age or sex structure of the population, disease, competition with livestock and other wildlife species, as well as interactions between these factors (Ballard et al., 2001; Mech and Nelson, 2000). For example, Van Ballenberghe and Ballard (1994) found that wolf predation was a limiting factor in the recovery of a reduced moose population in Alaska, when there was minimal human influence, little alternative prey, and additional predation by brown bears.

Severe weather appears to be the primary limiting factor for ungulate populations in Yellowstone, Minnesota, and Wisconsin. Although elk are the primary prey for Yellowstone wolves (>90%), the Yellowstone Northern Range elk herd, following a substantial winter die off in 1996/1997 and subsequent high hunter-harvests in the spring of 1997, has recovered (D. Smith, 2001). Overall, the elk herds have remained very stable throughout wolf recovery (D. Smith, 2000), possibly because wolves are preying on very old elk that might otherwise die off in the winter (Houston, 1978; Singer and Mack, 1999). In Minnesota, despite high wolf numbers, white-tailed deer have recovered quickly from a reduction of 45%-50% due to severe winters in 1995/1996 and 1996/1997 (MN DNR 2001). Furthermore, according to its 2001 Wolf Management Plan, Minnesota has, for more than 20 years, and with an ever increasing wolf population, "successfully managed deer populations at levels that have provided increasing hunter-harvests and ample prey for wolf recovery and persistence, despite variable winter conditions, highway collision losses, other predation, and other mortality factors" (MN DNR 2001, p.26). In Wisconsin, an analysis of wolf impacts on deer concluded, "it appears that habitat and climatic effects have greater impacts on deer population trends than wolf predation" (WWAC, 1999, p.58).

These studies suggest that a recolonizing wolf population would not significantly affect Utah's ungulate populations. For example, estimated predation rates obtained from intensive studies in Yellowstone (Phillips and Smith, 1997; D. Smith, 1998; D. Smith et al., 1999b), Idaho (Husseman and Power, 1999) and the northern Great Lakes Region (WWAC, 1999) which range from 12.4-18 ungulates killed per wolf per year, indicate that a population of 200 wolves should kill no more than 3,600 wild ungulates each year in Utah. Although only rough estimates of current population numbers for Utah ungulates are available, the Utah DWR winter population objectives for 2000 suggest that Utah could potentially support a mule deer population of approximately 480,000 and an elk population of approximately 74,000 (UT DNR 2001b). These population objectives are, by definition, overestimates of the actual population at any given time, but are useful in evaluating the likely impact of wolf predation. Whether or not wolf predation would constitute compensatory or additive mortality, these figures suggest that a wolf population of 200 would not significantly decrease overall ungulate populations in Utah. For comparison, it has been variously estimated that Utah motorists kill at least 2,000-5,500 (Romin and Bissonette, 1996), or more than 7000 (Messmer, 2001), deer each year. Additionally, Utah's hunters in 1999 harvested 34,433 deer and 13,188 elk (UT DWR, 2001b). It is important to note, however, that because the wolf population would not be spread evenly among all ungulate populations, wolves might have substantial impacts on

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ungulates in some areas. The magnitude of these potential local impacts is difficult to predict.

4.4.2. Ungulate Behavior

Wolf recolonization, on the other hand, may influence ungulate behavior in Utah. Berger (1998) proposed that when specific predators are absent for generations, prey might lose their ability to recognize and avoid those predators, and actively defend against them. If this was the case, then recolonizing wolves might be expected to have a significant advantage over these "naïve" prey. Alternatively, prey might adjust their behavior relatively rapidly, leading to changes in group size, vigilance, or shifts in habitat use. Recently, Berger et al. (2001) found that female moose in the Greater Yellowstone Ecosystem have developed hypersensivity to wolf howls. Elk at the National Elk Refuge in Wyoming have increased vigilance and formed tighter groups (B. Smith and Berger, 2001). Additionally, when wolves hunted near the National Elk Refuge, elk routinely dispersed to other feeding grounds, where they congregated in larger numbers and may have enjoyed better visibility of approaching predators (USFWS et al., 2001). Thus, at least in these cases, ungulates have adjusted their behaviors within a single generation, suggesting that wolf restoration will not decimate naïve prey populations in Utah.

Although the Yellowstone elk herds have remained very stable throughout wolf recovery, elk may be shifting their habitat use away from high wolf-use riparian areas. Since the reintroduction of wolves in Yellowstone, large areas of riparian willow have begun to recover from overgrazing by elk. One interpretation of these data is that wolves are altering habitat use by elk, and reducing browsing on riparian willows. Wolf recovery may also aid in the restoration of aspen groves (Chadde and Kay, 1988). Researchers have discovered that most aspen groves in Yellowstone have not regenerated themselves since the 1920s, coinciding with the extirpation of wolves. Ripple and Larson (2000) hypothesize that wolves may be responsible for increasing aspen recruitment in Yellowstone in recent years by influencing elk movements and browsing patterns. Consistent with these findings, Singer and Mack (1999) predict that elk may increase their use of forest cover to escape wolves. We would expect similar changes in ungulate behavior in Utah in response to the presence of wolves during recolonization.

4.4.3. Predators and Scavengers

Wolf recovery will probably also have impacts on other predators and scavengers (e.g. Leopold, [1937] 1995). Wolf reintroduction and recovery in other areas has changed the abundance and distribution of many predators and scavengers. Through direct predation, wolves reintroduced into Yellowstone have reduced the Lamar Valley coyote population by 25% to 33% each winter (Crabtree and Sheldon 1999). Furthermore, behavioral changes have been observed in surviving coyotes (Switalski, 2002).

The reduction, displacement, and behavioral changes of coyotes may have a cascading effect throughout the ecosystem. Prior to wolf reintroduction, coyotes in the Lamar Valley annually removed 76% of microtine vole, 23% of pocket gopher, 35% of ground squirrel populations from the northern range of Yellowstone (Crabtree and Sheldon 1999). The return of the wolf has reduced predation pressure from coyotes on these

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populations, and predators such as foxes, hawks, owls, eagles, badgers, and pine martens may be benefiting from additional prey availability. Additionally, displacement or reduction of the coyote population may decrease coyote predation on ungulate neonates (Singer and Mack, 1999; UT DWR, 2001b; Power, 2001), and foxes (Harrison et al., 1989). Anecdotal evidence suggests that wolves may also influence cougar and black bear behavior and populations.

Prior to wolf reintroduction into Yellowstone, scavengers relied heavily on ungulate winterkill and neonates for food. Since reintroduction, scavengers have benefited greatly from the consistent year-round supply of wolf-killed ungulates. Preliminary findings show that grizzly bears, coyotes, foxes, ravens, magpies, bald eagles, and golden eagles are all using wolf-killed carcasses, and anecdotal evidence suggests that populations of many of these species are increasing (with the exception of coyotes; C. Wilmers, Yellowstone Ecological Research Center, in preparation).

4.4.4. Conclusion
In conclusion, research is continuing to document the effects of wolf recovery on ecosystems. In addition to direct impacts, there are many indirect effects, including trophic cascades. Most of these effects are positive, and appear to be increasing overall ecosystem integrity. As wolves inevitably begin to recolonize Utah, land managers should be prepared to address these ecosystem impacts. It will be essential to monitor and research the recolonizing population. Radio-collaring and monitoring of wolves will allow managers to monitor their dispersal, distribution, proximity to livestock, and aid in law enforcement, as well as determining wolf habitat use, seasonal food habits, predation rates, breeding and denning activity, causes of wolf mortality, corridor use, and overall effects on Utah's ecosystems. We recommend that, in addition to monitoring the wolf population, the state of Utah begin a comprehensive program to monitor ungulate populations. This will allow not only an assessment of how wolves may be impacting those populations, but may also improve ungulate management in general, and thereby overall habitat quality.