The Feasibility of Gray Wolf Reintroduction to the Grand Canyon Ecoregion

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Abstract
*As part of a regional conservation planning initiative, this study is being undertaken to determine the biophysical and socioeconomic feasibility of reestablishing a top carnivore, the gray wolf (*Canis lupus*), in the Grand Canyon Ecoregion (GCE). The GCE is a roughly 1.5 million km^2 area located on the southern Colorado Plateau. The last remaining gray wolves were probably eradicated in the 1920s and 1930s. Because of an interest in restoring extirpated native species to this ecoregion, and the desire to increase the size of the gray wolf metapopulation in the Southwest, there is need for an objective and spatially explicit landscape-scale model of potential gray wolf habitat. The first phase of this conservation GIS analysis involves utilizing six habitat characteristics or factors—vegetation cover, surface water availability, prey density, human population density, road density, and land ownership—to identify and describe potential reintroduction sites in the Arizona section of the Grand Canyon Ecoregion. Initial results show that there are at least two localities in northern Arizona suitable for reintroduction of around 100 wolves. This paper is a preliminary report on observations, results, and some recommendations deriving from the feasibility study.*

Introduction
Conservation biologists have shown that large or top carnivores are often keystone species whose removal jeopardizes the maintenance of ecological integrity in large-scale ecosystems (Soule and Noss 1998; Terborgh et al. 1999). Therefore, conservation planners interested in restoring and protecting large ecosystems or ecoregions emphasize recovery of top predators. The primary goal of this study—which is supported by the Grand Canyon Wildlands Council, Defenders of Wildlife, and Prescott College—is to determine the capability and suitability (together, the feasibility) of reintroducing one top carnivore, the gray wolf (*Canis lupus*), to the Grand Canyon Ecoregion (GCE) (Figure 1).

Ultimately, this study will address 26 factors or aspects, grouped into two dimensions—biophysical and human—that are expected to affect the feasibility of wolf recovery in the entire GCE (Sneed and Crumbo 1998). This paper, however, will focus on current, preliminary results from research done on a limited number of factors in the northern Arizona section of the ecoregion (see Figure 1).

Historic occurrence and taxonomic position
To accurately reconstruct the historic distribution of gray wolves in the GCE is challenging for a variety of reasons. Nineteenth century writers often accidentally or purposefully misidentified coyotes (*Canis latrans*), wolves, and wolf-dog hybrids (Gipson et al. 1998). Wolf hunters and trappers sometimes exaggerated the number of wolves in an area to enhance their job security and occasionally misrepresented where a wolf was killed in order to claim a local bounty. Furthermore, the widespread use of poisons meant that many animals, including wolves, were dispatched without any record of their death.

Regardless of inaccuracies in the historical record, a partial picture of where wolves occurred prior to their extermination in the Southwest can still be pieced together. These records show that at least small populations of wolves were found throughout the woodlands and forests of northern Arizona (Brown 1984). For example, from these records we know that there were at least 30 wolves on or near the North Kaibab because of the number reported killed between 1907 and 1926 (Russo 1964). Brown (1984) claimed that "the last wolf in this part of northern Arizona was taken on the Paria Plateau about 1928", but a former Civilian Conservation Corps worker recently reported that he saw wolves on three different occasions in 1935 on the North Rim of Grand Canyon National Park (GCNP) (Leslie, personal communication). Moreover, "as recently as March 3, 1948, assistant chief ranger A.L. Brown reported wolf tracks in fresh snow in the area of Bright Angel

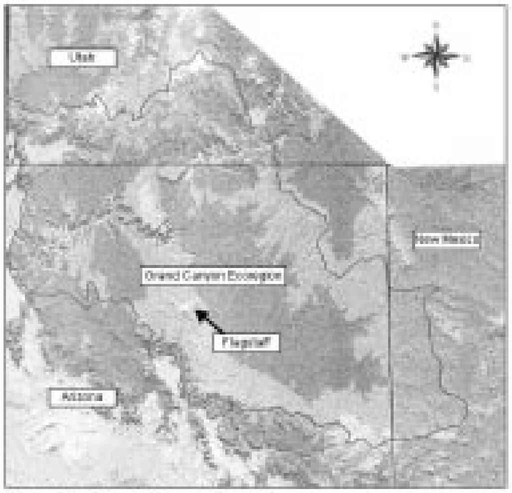

Figure 1. Grand Canyon ecoregion

Point" on the North Rim of GCNP (Hoffmeister 1971). Finally, the last wolf inhabiting the Mogollon Rim area in the southern part of the GCE was reportedly taken in 1942 (Hoffmeister 1986). Clearly, gray wolves occurred within the Grand Canyon Ecoregion well into the twentieth century, although their exact numbers and range will probably never be known with certainty.

Due to the taxonomic splitting approach of the time, Young and Goldman (1944) identified 23 subspecies of North American gray wolves (based on skull measurements, pelage color, and size) and mapped their geographic distribution. Two of these 23 nominal subspecies—*C.l. mogollonensis* (the Arizona wolf), *C.l. youngii* (the Great Basin or Intermountain wolf), and, possibly, *C.l. baileyii* (the Mexican wolf)—inhabited the Grand Canyon Ecoregion (Brown 1984; FWS 1996). Development of similar classification schemes continued into the 1970s (e.g., Hall and Kelson 1959) until some taxonomists began questioning the splitting tradition of wolf taxonomy.

Modern lumping systems of wolf taxonomy are based on multivariate statistical analysis of large sample sizes and confirmed by the results of contemporary molecular genetics (Wayne et al. 1992). Adopting this approach, Nowak (1995) lumps the two previously identified GCE wolf subspecies, (*C. l. mogollonensis* and *C. l. youngii*), in with the geographically widespread subspecies *C. l. nubilus*. Nowak (1995) also affirms the validity of a truly Southwestern subspecies, the Mexican wolf (*C. l. baileyii)*, which may have occupied or dispersed into the southeastern part of the GCE.

Habitat capability and suitability mapping

Restoration of viable large carnivore populations is probably among society's greatest challenges, requiring extraordinary innovation and cooperative management on an ecoregional scale (Paquet and Hackman 1995). Furthermore, solutions to large predator conservation are economic, sociological and political (human dimension issues), as well as biological and ecological (biophysical factors) (Clark et al. 1996). The feasibility of wolf recovery depends on the capability and suitability of habitat for sustaining wolf populations. Although many factors can and should be considered, the ultimate determinants are ungulate prey and human impact (Fuller et al. 1992) or, put another way, sustenance and security.

Course screen landscape-scale habitat mapping for the Arizona portion of the GCE (see Figure 1) has been done following other similar studies (Mladenoff et al. 1995; Quinby et al. 1999; Ratti et al. 1999; Wydeven et al. 1998). Various biophysical factors can be considered in evaluating the capability of habitat to support wolves, but this study focuses on vegetation cover, surface water availability, and, most importantly, ungulate prey abundance. In addition to adequate food supplies, security from human disturbance and persecution are important factors affecting the suitability of a landscape for wolf recovery. At this stage in the research, three critical human dimension aspects are considered: human population density, road density, and land status.

Biophysical factors

Several reintroduction studies (e.g., Mladenoff et al. 1995) suggest that gray wolves, at least those living south of the Arctic, tend to prefer forested landscapes. Historically, in the Southwest, wolves were most commonly found associated with woodlands and montane forests (Groebner et al. 1995; FWS 1996). When observed elsewhere, such as in grasslands, they were probably simply passing through as they moved between their preferred habitat of forested highlands. Figure 2 maps the distribution of these two vegetation types, as well as others such as shrublands and grasslands. This figure plainly illustrates a broad band of forestlands-woodlands extending north-south from the Kaibab Plateau, through the Flagstaff area to the Mogollon Rim, interrupted only by the Grand Canyon and urbanized areas such as Flagstaff. Other areas of woodland/forest vegetation types are found in isolated mountain areas of the Arizona Strip as well as the Hualapai and Navajo Indian Reservations.

Because wolves require large amounts of water to aid digestion (Lopez 1978; Mech 1970), several studies of wolves in the Southwest (Groebner et al. 1995; FWS 1996) and elsewhere (Quinby et al. 1999) have suggested that the availability of free water is an important determinant of gray wolf abundance and distribution. Figure 3 illustrates the distribution of currently mapped lakes, springs, and streams in the Ari-

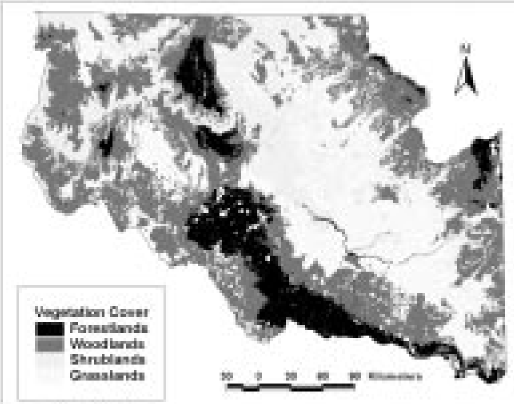

Figure 2. Vegetation cover

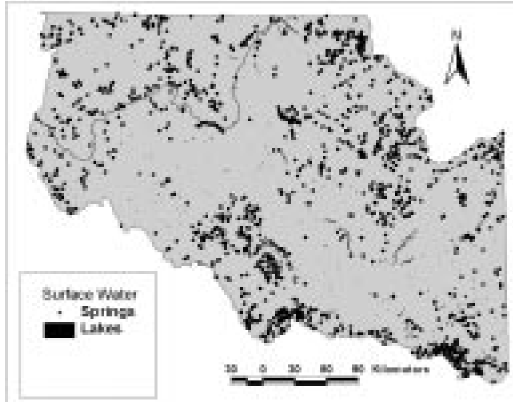

Figure 3. Surface water

zona portion of the Grand Canyon Ecoregion. Although the digital data available is very incomplete, this figure shows that there are more than enough sources of surface water on the Kaibab Plateau, in the Flagstaff area, and along the Mogollon Rim. This conclusion is supported by the observed presence of relatively high numbers of other large predators (e.g., mountain lions (*Felis concolor*) and prey species in these locales.

Clearly, one of the most important determinants of suitable wolf habitat is the abundance of ungulate prey species. The primary prey species for wolves in the Grand Canyon Ecoregion are mule deer (*Odocoileus hemionus*), followed in order of importance by elk (*Cervus elaphus*), pronghorn (*Antilocarpa americana*), and bighorn sheep (*Ovis canadensis*). Information about abundance (density) and distribution of these wildlife species in the Arizona part of the ecoregion was obtained from the Arizona Game and Fish Department. Figures 4 and 5 display the approximate density of mule deer and elk populations in Arizona GCE.

Other reintroduction studies (e.g., FWS 1996) indicate that a density of approximately two to six deer per km^2 would be required to support a Mexican wolf population and, presumably, similar numbers would be adequate for wolves in the GCE. Figure 4 demonstrates that much of the Kaibab Plateau enjoys a very high density of mule deer (eight to 13 animals per km^2), while the remainder of the area has an adequate density of three to eight deer per km^2. The Coconino Plateau around Flagstaff also supports quite dense populations (three to eight per km^2). Furthermore, similar densities probably exist on parts of the Hualapai and Navajo reservations in the GCE, but no data is readily available to confirm this supposition. Even if the current mule deer population density is one-half of what these figures indicate, as some Arizona Game and Fish Department personnel suggest (e.g., Goodwin, personal communication), there are still more than sufficient deer densities to support gray wolves. Figure 5 shows that elk densities, while somewhat lower on average than mule deer, are quite high (i.e. two to three animals per km^2) around Flagstaff and southeast along the Mogollon Rim. Of course, elk also average three times the biomass of deer. Figures 4 and 5 combined map an adequate ungulate prey base extending north-south from the Kaibab Plateau, through the Flagstaff area, and southeast along the Mogollon Rim.

Human dimensions

An important determinant of habitat suitability for gray wolves and other large carnivores such as grizzly bears (Merrill et al. 1999) seems to be human population density. Studies (e.g., Mladenoff et al. 1995; Ratti et al. 1999) have shown that lands with a human population density greater than 12 to 13 persons per square kilometer will not be suitable wolf habitat. The map displayed in Figure 6 indicates that most of the Arizona section of the Grand Canyon Ecoregion has population densities less than 13 persons per km^2. Except for the Flagstaff-Sedona urban zone, the entire north-south corridor from the Kaibab Plateau to the eastern, slightly urbanized, part of the Mogollon Rim has a human population density of less than four people per km^2. Not surprisingly, this same corridor has high prey species densities and seems capable of supporting wolves.

Wolves are usually not threatened by roads, except when they are struck by motor vehicles (Mech 1977). Nonetheless, roads can provide access to generally undisturbed areas where humans may harass or kill wolves. Studies of road density and wolf distribution relationships by Thiel (1985) and Mech et al. (1988) suggest a road density threshold value of between 0.6 and 0.8 kilometers of road per square kilometer of area. Higher road density values generally result in unsuccessful breeding attempts. Mladenoff et al. (1995), using radio collar data on recolonizing wolves in northern Wisconsin, discovered that road density and fractal dimension—reflecting the degree of habitat fragmentation (often the result of road building)—were the most important predictors of favorable wolf habitat. Figure 7 shows that most of the north-south corridor, extending from the Kaibab Plateau through to the Mogollon Rim southeast of Flagstaff, has road densities higher than 0.68 km per km^2, but generally lower than 1.4 km per km^2. Road density in many parts of the GCE is somewhat higher than recommended in other studies, but most of the numerous roads in the ecoregion are tertiary or unimproved roads that could be eliminated on public lands with a vigorous road-closing program. Furthermore, the low human density numbers (Figure 6) might indicate that these areas are favorable wolf recovery habitat despite the existence of relatively high unimproved road densities.

Favorable land status, defined here as lands in public ownership and, especially, designated protected areas, can help make a landscape suitable for gray wolf reintroduction (Southern Rockies Ecosystem Project, 1998). Identifying, describing, and mapping proposed and designated wilderness areas and other areas designed to protect ecological processes or wildlife, such as the Grand Staircase/Escalante National Monument and the Grand Canyon Game Preserve in the Kaibab Forest (Miller 1996) is especially important. Figure 8 maps distribution of public lands, both state and federal, exclusive of Indian reservations. This reveals that a wide band of federal public lands (including large tracts of protected areas) runs north-south from the Kaibab Plateau through the Flagstaff area and southeast along the Mogollon Plateau (again, corresponding with the distribution of important biophysical factors). State lands, even though currently interspersed in a "checkerboard" fashion (see Figure 8) with private and federal lands, could be consolidated through land trades and purchases to create wildlife corridors between federal public lands such as the Coconino and Kaibab National Forests.

The landscape-scale habitat mapping, included in this progress report, is admittedly somewhat incomplete at this stage in the research. Nonetheless, the mapped variables of both biophysical and human dimensions point strongly towards the probability that at least two areas—the Kaibab Plateau and much of the Mogollon Rim south and east of Flagstaff—are capable of supporting viable wolf populations and suitable for reintroduction of gray wolves

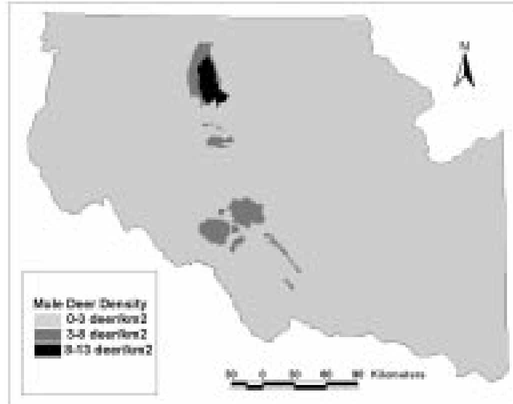

Figure 4. Mule deer density

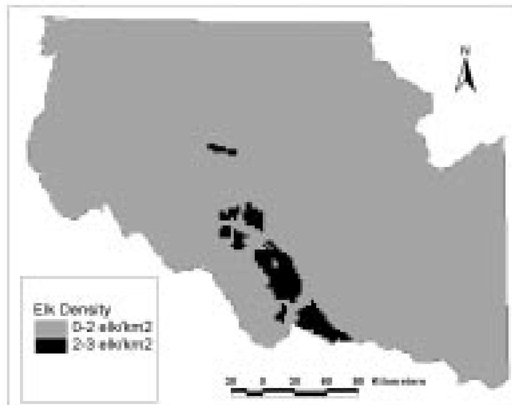

Figure 5. Elk density

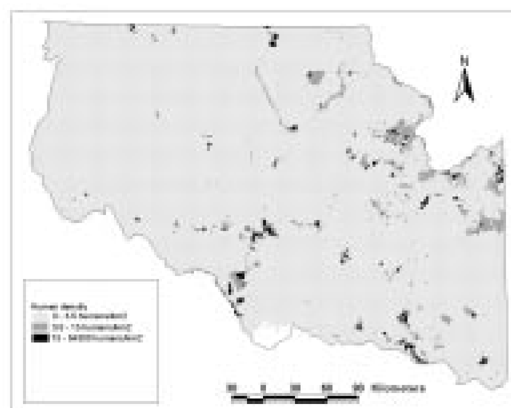
Figure 6. Human density

Projected wolf densities

Assuming that wolf reintroduction is feasible, it is reasonable to ask how many wolves might the Arizona portion of the Grand Canyon Ecoregion support. Utilizing the existing deer and elk density distribution maps (Figures 4 and 5), and following Fuller (1989), very preliminary calculations of predicted wolf density were done using these equations:

$$W = 3.4 + 3.7D$$

and

$$W = 3.4 + 3.7(3E)$$

where W is predicted wolf density (per 1000 km^2), D is estimated mule deer density (per km^2), and $3E$ is estimated elk density (per km^2) times a relative biomass value (elk biomass is 3 x 1 deer). Both low and high ungulate density estimates were utilized in calculating a range of predicted wolf numbers shown in Table 1.

Although this facet of the study is far from finished, historical records and initial carrying capacity research suggest that to reintroduce at least 100 gray wolves into the Arizona portion of the Grand Canyon Ecoregion would be feasible.

Potential stock for wolf reintroduction

When the time comes to make a decision about reintroducing gray

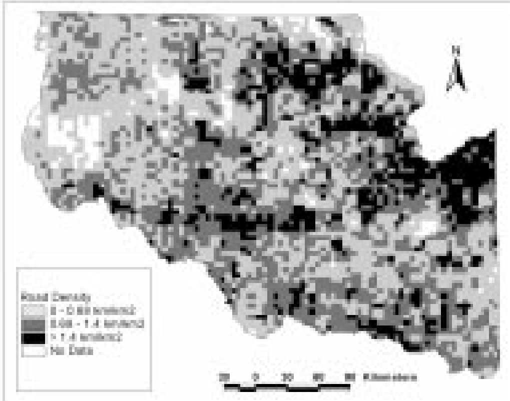

Figure 7. Road denisty

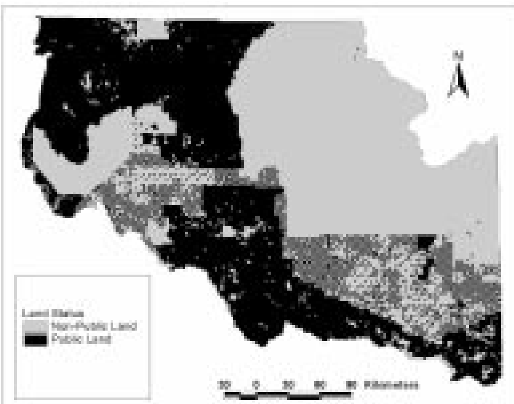

Figure 8. Land status

wolves to the Grand Canyon Ecoregion, we should "…consider behavioral or demographic factors to be more important than maintenance of the genetic purity of putative wolf subspecies…" (Wayne et al. 1992). If Nowak's (1995) recent revision of wolf taxonomy is accepted, it seems biologically appropriate that stock for reintroduction could be taken from anywhere in the historic range of *C. l. nubilus*. While finding areas of surplus wolf populations with habitat exactly comparable to the GCE will be difficult, regions such as the Great Lakes, currently supporting *C.l. nubilus* populations, do exhibit analogous forested ecosystems (albeit different forest types) and have similar ungulate prey species (i.e., deer and elk). Wild wolves translocated from the Great Lakes region, for example, would at least be habituated to forest habitats (as opposed to tundra) and experienced in hunting the types of ungulate species that are most abundant in the GCE.

Alternatively, captive or wild-bred Mexican wolves (*C.l. baileyii*) could be utilized for reintroduction. Given the difficulties experienced with captive bred stock in the current Mexican wolf recovery effort, however, it seems best to wait for the availability of surplus wild-raised stock GCE (Parsons, personal communication). Also, when the Mexican wolf population reaches a viable size in the wild, dispersers from eastern Arizona and western New Mexico will likely attempt to colonize the southeastern part of the GCE. Thus, this recovery opportunity in the GCE could help extend the geographic range and metapopulation of the currently recovering, but still endangered, Mexican wolf.

Conclusions

The first phase of this landscape-scale analysis involved utilizing six factors of the biophysical and human dimensions to identify and describe potential reintroduction sites in the Arizona section of the Grand Canyon Ecoregion. Initial results show that there are at least two localities in northern Arizona available for reintroduction of around 100 wolves. Source stock for wolf recovery in the GCE could come from existing large *C. l. nubilus* populations in the Great Lakes and/or a recovered *C. l. baileyii* population in the Southwest. Clearly, the future extension of wolf recovery into northern Arizona and other parts of the GCE will have to be done under the legal mandate of the ESA and will most likely be sponsored by a federal agency such as the Fish and Wildlife Service and/or National Park Service.

Further investigation and study will continue to refine the habitat capability and suitability analyses, as well as to help determine the most appropriate subspecies for wolf reintroduction in the ecoregion. In the end, however, the most important consideration is how to best assist nature in restoring gray wolves to the Grand Canyon Ecoregion and thereby help in the national effort to conserve this magnificent and ecologically essential carnivore.

Acknowledgements

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Table 1. Minimum and maximum number of wolves predicted to occupy Arizona part of Grand Canyon Ecoregion based on combined mule deer and elk densities and areas.

Location	Area (square kms)	Wolves (pop. range)
North Kaibab	1472	35 to 62
South Colorado Plateau	3849	80 to 125
Total Arizona GCE	5321	115 to 187

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