Draft Mexican Wolf Conservation Assessment

U.S. Fish and Wildlife Service
Southwest Region (Region 2)
Albuquerque, New Mexico

Disclaimer

Data from the Mexican Wolf Blue Range Reintroduction Project used in this document spans from 1998 to August 1, 2008, or for a range of years within this time period. Some data is only available in published form in annual reports, and thus is reported only through 2007. After the public comment period, the final conservation assessment will be updated with new data as appropriate.

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Most importantly, the Southwest District Population Segment (SWDPS) Recovery Team, especially the Technical Subgroup, contributed the ideas that form the foundation of this document. This recovery team was convened by the Southwest Region of the Service in 2003 to revise the 1982 Mexican Wolf Recovery Plan. This document intends to capture the scientific concepts and information that they discussed before the planning process was put on hold by the Service in 2005 due to litigation. Their work has not been resumed, although the agency maintains its intent to develop a revised plan when circumstances permit.

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FOREWORD

A conservation assessment, unlike a recovery plan, is not a document required by or defined in the Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. 1531 *et seq*.) or related policies. It has no predetermined format or content mandated by law or policy. Rather, this is a unique document developed in response to the unique needs of the Service at this time. It has been over 20 years since the completion of the 1982 Mexican Wolf Recovery Plan, and an up-to-date description and assessment of the gray wolf (*Canis lupus*) recovery effort in the Southwest is needed.

The purpose of this conservation assessment is to provide information relevant to the conservation and recovery of the gray wolf. Specifically, the document may provide background information needed for future gray wolf recovery planning or policy decisions pertaining to the southwestern region of the country. The scope of the document is limited to biological science and related disciplines in order to provide an up-to-date assessment of and scientific basis for gray wolf recovery in the Southwest. The social and economic facets of gray wolf recovery are recognized as equally important, but are beyond the realm of information this document strives to provide.

The terms used to identify the wolf that is the subject of this conservation assessment are subtle but distinct. The generic gray wolf, *Canis lupus*, is the entity listed on the List of Endangered and Threatened Wildlife (50 CFR 17.11(h)) and protected by the ESA; therefore, it is appropriate from a policy, and at times biological, standpoint to use the term "gray wolf." Due to the Service's regional division of gray wolf recovery efforts, it is also useful at times to refer to the gray wolf in specific regions of the country. Thus, when the term "gray wolf" is used in reference to the Service's gray wolf recovery programs in the Mountain-Prairie and Pacific regions or the Great Lakes, Big Rivers Region, it describes the gray wolves located there. In the Southwest, the situation becomes more complex. Here, the regional gray wolf recovery focus has been on the Mexican gray wolf (Mexican wolf), *Canis lupus baileyi*, a subspecies of gray wolf that historically inhabited the southwestern region of the United States and Mexico. Since this program, from a policy standpoint, is a regional program for gray wolf recovery, the assessment refers to "gray wolf recovery in the Southwest." The assessment uses the term "Mexican wolf" when providing biological information specific to the subspecies, as well as in the context of the agency's commitment to conserve the subspecies, the ongoing Mexican wolf reintroduction and captive breeding program, and the subspecific focus of the 1982 Mexican Wolf Recovery Plan. While these various terms are used for clarity and adherence to policy, they may unfortunately cause confusion. However, the assessment does not change the listed status of, commitment to, focus of, or any other aspect of the Service's existing wolf program in the Southwest Region or any other region.

The Southwest Region of the Service includes the states of Arizona, New Mexico, Oklahoma, and Texas. Gray wolf recovery efforts to date have taken place in Arizona and New Mexico, namely the reintroduction of the Mexican wolf to the wild. However, southern portions of Colorado and Utah have been included in recent Service policy decisions related to the Southwest that were overturned by court decisions (see Status and Implications of

National Gray Wolf Recovery for the Mexican Wolf). Thus, the assessment does not attempt to define "Southwest" or "southwestern" in recognition that such definitions are context dependent, but instead uses these terms broadly as a general reference to this region of the country. When precise locations are required for accuracy, they are provided.

The document is organized in three main sections. "History of the Gray Wolf Recovery Program in the Southwest" briefly reviews the decline of the gray wolf in the Southwest and the inception of national recovery efforts for the gray wolf pursuant to the ESA, focusing on the development of a captive breeding program and reintroduction project for the Mexican wolf. "Gray Wolf Biology and Ecology" provides an overview of basic gray wolf biology and ecology, with descriptive information on the Mexican wolf where available and informative. Synthesized data from the 5-Year Review of the reintroduction project is provided throughout this section, in some cases updated with annual data from the years following the review (2003-July 2008). "Conservation Assessment" assesses the gray wolf recovery effort in the Southwest by conducting a 5-factor analysis to ascertain the security of the reintroduced population and by identifying the conservation principles that provide the foundation for gray wolf recovery and discussing the degree to which the current recovery effort in the Southwest embodies these principles. "Summary statements" throughout the document serve as focal points of the assessment. These statements are not recommendations, nor do they have any regulatory standing. Rather, they are provided as a communication tool.

EXECUTIVE SUMMARY

HISTORY OF THE GRAY WOLF RECOVERY PROGRAM IN THE SOUTHWEST

The Mexican wolf was listed as an endangered subspecies in 1976 due to near extinction resulting from predator extermination programs in the late 1800s and early to mid-1900s. This subspecies of gray wolf historically inhabited the southwestern United States and Mexico. In 1978, the Service subsumed this and several other gray wolf subspecies listings into a species-level listing for the gray wolf in order to protect the species throughout its range in the coterminous United States and Mexico. The Service initiated three regional recovery programs for the gray wolf; in the Southwest Region, a recovery plan was developed for the Mexican wolf, solidifying the regional gray wolf recovery focus on the conservation of this subspecies. The 1982 Mexican Wolf Recovery Plan recommended a two-pronged approach to recovery (i.e., establishment of a captive breeding program and reintroduction of wolves to the wild) but did not establish recovery criteria for the region, as did the 1992 Recovery Plan for the Eastern Timber Wolf and the 1987 Northern Rocky Mountain Wolf Recovery Plan for their respective regions of the country. A range-wide recovery plan for the gray wolf has never been developed.

Today, an international Mexican wolf captive breeding program has been established and Mexican wolves have been reintroduced to the wild in Arizona and New Mexico in a nonessential experimental population pursuant to section 10(j) of the ESA. The reintroduced Mexican wolf population numbers approximately 50 wolves, the halfway point of the 10(j) objective to establish a single population of at least 100 wolves. The growth of this population has lagged behind initial projections for achieving the population objective, likely due to a combination of biological, sociological, and regulatory factors.

Although substantial progress in implementing the 1982 Mexican Wolf Recovery Plan has been achieved, a revised recovery plan has never been developed to establish recovery criteria for the region. Thus, other than the population objective for the reintroduced Mexican wolf population in Arizona and New Mexico, the gray wolf recovery effort in the Southwest operates without any guidance in terms of the number and distribution of wolves considered adequate for recovery and delisting.

GRAY WOLF BIOLOGY AND ECOLOGY

The gray wolf, *Canis lupus*, is a member of the dog family *(Canidae; Order Carnivora).* Five subspecies of gray wolf are currently recognized in North America, including the Mexican wolf.

Gray wolves are typically a mottled gray, but pelt color can range from white, cream, brown and red, to dark gray and black. Mexican wolves tend to be patchy black, brown to cinnamon, and cream in color. Gray wolves typically weigh between 80-120 lbs, are 5-6.5 ft long from tip of nose to tip of tail, and 2-2.5 ft high at the shoulder. The Mexican wolf is somewhat smaller; adults weigh 50-90 lbs with a length of 5-6 ft and height at shoulder 2-2.5 ft.

Wolves typically live 4 to 5 years in the wild, reaching sexual maturity at 2 years of age. Female wolves produce a litter of several pups each spring. Offspring remain with their family until they disperse to establish a new territory. These hierarchical family units are referred to as packs.

Wolves are top predators that have flexibility in using different prey and habitats. Historically, wolves occupied every habitat in the northern hemisphere that supported populations of large hoofed mammals (ungulates). Wolf packs establish territories in which they hunt for prey, primarily pursuing medium to large hoofed mammals. Historically, Mexican wolves were associated with montane woodlands characterized by sparsely- to densely-forested mountainous terrain and adjacent grasslands in habitats found at elevations of 4000-5000 ft where ungulate prey were numerous.

Wolves may interact with other predators, including coyotes (*C. latrans*), mountain lions (*Puma concolor*), and black bears (*Ursus americanus*). Wolves may also interact with humans, although wild, unhabituated wolves are generally not considered a threat to humans.

CONSERVATION ASSESSMENT

Threats to the Gray Wolf in the Southwest

Species are listed as threatened or endangered if it is determined that one or more of the following five factors in section 4(a)(1) of the ESA are responsible for their condition. These five factors are reassessed periodically while the species is listed to evaluate its status and ensure that conservation actions are appropriately tailored to address current threats to the species.

(A) the present or threatened destruction, modification, or curtailment of its habitat or range
The three fundamental ecological conditions necessary for wolf habitat include large area size, adequate prey, and security from human-caused mortality. Threats related to the destruction, modification, or curtailment of these conditions do not likely threaten the Mexican wolf at the current time, based on an increase in the area available to reintroduced wolves since the project began, lack of indication that wolves are food-limited, and a relatively small number of vehicular-related wolf deaths each year (other sources of human-caused mortality are considered under Factor D and Factor E). Future habitat availability for wolves may decrease over time due to human population growth and resultant development on public and private lands.

(B) overutilization for commercial, recreational, scientific, or educational purposes
Overutilization for commercial, recreational, scientific, or educational purposes is not considered a threat to the Mexican wolf because the Service does not authorize legal killing or removal of wolves from the wild for commercial, recreational (i.e., hunting), scientific, or educational purposes, illegal killing or trafficking for pelts is not know to occur, and non-lethal techniques are used during Mexican wolf research in the reintroduced and captive populations.

(C) disease or predation

A number of viral, fungal, and bacterial diseases and endo- and ectoparasites have been documented in gray wolf populations. There is little research specific to disease or contaminant issues in Mexican wolves, and only one wolf death due to disease (distemper) has been documented in the wild population. Mexican wolves are routinely vaccinated for rabies, distemper, parvovirus, and corona virus before release to the wild from captive facilities. Disease is not considered a threat to the Mexican wolf based on known occurrences in the reintroduced population and the active vaccination program.

Predation is not considered a threat to the Mexican wolf because no wild predator regularly preys on wolves and only a small number of predator-related wolf mortalities have been documented in the reintroduced population.

(D) the inadequacy of existing regulatory mechanisms

A number of concerns have been raised regarding the adequacy or appropriate implementation of regulatory mechanisms being applied to the Mexican wolf reintroduction project, including: 1) the internal and external boundaries of the Blue Range Wolf Recovery Area (BRWRA), including the configuration of the Primary and Secondary Recovery Zones and the regulations governing removal of wolves due to boundary violations; 2) regulations or management procedures for livestock management (e.g., carcass removal); 3) management procedures related to livestock depredation (i.e., Standard Operating Procedure 13 (SOP 13)); 4) implementation of conservation actions by Federal agencies pursuant to section 7(a)(1) of the ESA; and, 5) the alleged transfer of management authority of the reintroduction project from Service to the AMOC; and 6) failure to complete a revision of the 1982 Mexican Wolf Recovery Plan with objective and measurable delisting criteria, as required by the ESA.

Modifications in implementation of ESA regulatory mechanisms that will support the reintroduction and recovery effort are being evaluated by the Service.

(E) other natural or manmade factors affecting its continued existence.

In the Southwest, illegal killing of wolves is the single greatest source of wolf mortality in the reintroduced population. However, human-caused mortality in the Blue Range population is in line with FEIS mortality-rate projections and is therefore not considered a threat to the population at the current time. Public opinion has long been recognized as a significant factor in the success of gray wolf recovery efforts and illegal killing of wolves by those opposed to wolf reintroduction and recovery efforts is proof of its importance. In the Southwest, extremes of public opinion vary between those who strongly support or object to the recovery effort. Illegal take of wolves provides an indication of the level of social tolerance of the Mexican wolf reintroduction. In the BRWRA, illegal shooting of wolves has been the biggest single source of mortality since the reintroduction began in 1998. Although combined sources of human-caused mortality are in line with project projections and are less than that observed in other gray wolf populations, the Mexican wolf could be more susceptible to population decline at a given mortality rate than other gray wolf populations, based on lower reproductive rates, smaller litter sizes, and combined sources of mortality.

When wolf mortalities are combined with wolf removals (which may function as the equivalent to mortality if the wolf is permanently removed), the combined mortality/removal rate is higher than projections and is occurring at a level inconsistent with natural population growth. Human-caused mortality of Mexican wolves, of which illegal shooting is a significant proportion, in combination with removal actions, are hindering the population's growth toward the population objective of at least 100 wolves.

The Conservation Principles of Resiliency, Redundancy, and Representation

The principles of *resiliency*, *redundancy*, and *representation* represent a recently popularized conceptualization of key elements of biological diversity conservation and provide a useful framework for discussing scientific concepts relevant to gray wolf conservation and recovery in the Southwest, including demography, environmental variability, and genetics. The Service has invoked these principles to describe recovery efforts for the gray wolf in the Northern Rockies and Great Lakes, and for consistency, the conservation assessment uses these principles in similar fashion.

Resiliency

The principle of *resiliency* suggests that species that are more numerous and widespread are more likely to persist than those that are not. That is, a species represented by a small population faces a higher risk of extinction than a species that is widely and abundantly distributed due to the sensitivity of small populations to stochastic (that is, uncertain) demographic events. In small populations, including those with a positive growth rate, it is more likely that a wide deviation from average birth or survival results could result in a decline toward extinction from which the population would not be able to recover. Thus, as a population grows larger and individual events tend to average out, the population becomes less susceptible to demographic stochasticity. There is not a single population size that will ensure persistence. Rather, populations of various sizes, vital rates, and biological and ecological characteristics will simply have different risks of extinction.

A variety of methods are available for estimating a species' likelihood of persistence/extinction risk, ranging from complex theoretical or simulation models to simple observation of existing populations or best professional judgment. Viable wolf populations have been estimated in the scientific literature and previous gray wolf recovery plans as those that number in the hundreds to the thousands, depending on a number of factors. A current, complete, peer-reviewed viability analysis of the objective to establish a population of at least 100 wolves in the Southwest has not been conducted to determine the extinction risk faced by this population. No other population objective (i.e., recovery criteria) has been determined for the Southwest Region upon which to evaluate the degree to which the current reintroduced population establishes or contributes to regional *resiliency*.

Redundancy

Redundancy refers to the existence of redundant, or multiple, populations spread throughout a species' range. It advances the notion that a species' likelihood of persistence generally increases with an increase in the number of sites it inhabits because it allows for populations to exist under different abiotic and biotic conditions, thereby providing a margin of safety that random perturbation (or, variation) affects only one, or a few, but not all, populations.

Random variations in the environment that in turn affect the demography of a population are referred to as environmental stochasticity. Environmental stochasticity may take the form of variation in available resources (e.g., prey base), or in direct mortality (e.g., a disease epidemic). Extreme environmental events, referred to as catastrophic, including events such as wildfire, drought, or a disease epidemic, may result in drastic, rapid population declines.

The scientific literature does not recommend a specific number or range of populations appropriate for conservation efforts, although rule of thumb guidelines for the reintroduction of a species from captivity recommends that at least two populations be established that are demographically and environmentally independent.

When a species is distributed in redundant populations, there are two possible relationships between the populations: they can be completely isolated from each other, or they can be connected with one another through the dispersal of individual animals. If connectivity between populations is desired, conservation efforts must ensure that the distance between populations is compatible with wolf dispersal abilities and that the habitat through which individuals will be dispersing is of sufficient quality and quantity to support immigration. Alternatively, artificial immigration between populations must be accomplished through the translocation of wolves by management. For a species that has been extirpated from so much of its historic range, explicit effort must be made to recreate redundancy.

Numerous habitat assessments have been conducted to identify possible areas for reestablishment of the gray wolf in Arizona, New Mexico, Utah, Colorado, and Mexico. However, the number of redundant populations and related connectivity appropriate for recovery in the Southwest has not been specified. The establishment of a single population provides the least amount of redundancy, and therefore the least possible security against extinction risk from environmental variation.

Representation

Representation refers to the genetic diversity represented by members of a population or species, specifying that higher levels of diversity better support ecological and evolutionary processes than low levels. *Representation* also suggests that a species should be conserved in a variety of habitats in order to conserve ecosystem structure and function.

Attention to genetic structure and diversity may be a critical component of conservation efforts for small populations due to the likelihood for genetic drift to occur. Genetic drift refers to genetic changes in populations due to random fluctuations in allele frequency. It can influence the persistence of a population through several outcomes, including loss of phenotypic variation, loss of adaptive potential, and the buildup of harmful mutations, including mitochondrial mutations. Small populations are also at greater risk of inbreeding depression (a reduction of fitness due to inbreeding) due to the smaller pool of unrelated potential mates available as compared to a larger population.

Effective population size can be defined as the size of the ideal population that will result in the same amount of genetic drift as the population being considered. Effective population size, rather than the census population size, provides a measuring stick for determining a population's risk of genetic drift and inbreeding. For the gray wolf, social structure greatly affects which wolves mate. The effective population size of a census population of 100 Mexican wolves has been estimated at approximately 28 wolves.

Several general (non-species specific) rules of thumb have been presented in the scientific literature to inform efforts for conservation of a species' or populations' genetic diversity, ranging from effective population sizes of several dozens of animals to avoid immediate fitness-related issues, to effective population sizes of hundreds to thousands of animals to preserve long-term adaptive potential.

Intensive management of genetic diversity has been an integral component of the Mexican wolf captive breeding program and reintroduction project due to the small number of founders upon which the captive breeding program was established. Management has focused on ensuring the representation of genes from each of the three founding lineages in both the captive and wild populations and on the continued maximization of overall gene diversity retention. Inbreeding depression has been observed in captive and reintroduced wolves. Determination of an effective population size for regional gray wolf recovery in the Southwest has not been made, and thus the degree to which the reintroduced population contributes to *representation* cannot be evaluated.

CONCLUSION

The gray wolf recovery effort in the Southwest Region consists of a Mexican wolf captive breeding program and a reintroduction project to reestablish a population of at least 100 wolves in the wild. As envisioned by the 1982 Mexican Wolf Recovery Plan, these efforts have ensured the survival of the Mexican wolf. Although lagging behind population growth projections, the current reintroduced population is relatively secure from threats.

However, recovery criteria have not been developed to provide a broader perspective for the significance of the reintroduced population. Consideration of the principles of *resiliency*, *redundancy*, and *representation* suggest that larger populations have less extinction risk than smaller populations, multiple populations enhance the likelihood of species' persistence more than a single population, and short-term fitness and long-term adaptive potential of populations is best supported by establishing larger, rather than smaller, effective population sizes. Although the degree to which the Blue Range population contributes to resiliency, redundancy, and representation is precluded by a lack of recovery criteria against which the population objective to establish a single population of at least 100 wolves can be evaluated, it is clear that the establishment of this population does not achieve *resiliency*, *redundancy*, or *representation*.

ABBREVIATIONS AND ACRONYMS

AGFD	Arizona Game and Fish Department
AMOC	Adaptive Management Oversight Committee
AMWG	Adaptive Management Working Group
APA	Administrative Procedures Act of 1946
AZA	Association of Zoos and Aquariums
Blue Range population	Wolves in the BRWRA, FAIR, and surrounding areas
BRWRA	Blue Range Wolf Recovery Area
DPS	Distinct Population Segment
EIS	Environmental Impact Statement
ESA	Endangered Species Act of 1973, as amended
FAIR	Fort Apache Indian Reservation
FEIS	Final Environmental Impact Statement of 1996 (for proposed reintroduction of Mexican wolves
Final Rule	Final "nonessential experimental population" or "10(j)" rule of 1998 for Mexican wolf reintroduction in Arizona and New Mexico
Great Lakes	USFWS gray wolf recovery program administered out of the Great Lakes, Big Rivers Region (Region 3)
IFT	Interagency Field Team (for the Reintroduction Project, see below)
MVP	Minimum Viable Population
MWEPA	Mexican Wolf Experimental Population Area
NEPA	National Environmental Policy Act of 1969
NMDGF	New Mexico Department of Game and Fish
Northern Rockies	USFWS gray wolf recovery program administered out of the Mountain-Prairie Region (Region 6) and Pacific Region (Region 1)
PVA	Population Viability Analysis
SOP	Standard Operating Procedure for the Reintroduction Project
SSP	Species Survival Program
SWDPS	Southwestern Gray Wolf Distinct Population Segment
USDA-WA	US Department of Agriculture-Animal Plant Health Inspection Service Wildlife Services
USFWS	US Fish and Wildlife Service
USFS	USDA Forest Service
WMAT	White Mountain Apache Tribe

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HISTORY OF THE GRAY WOLF RECOVERY PROGRAM IN THE SOUTHWEST

The Decline of the Gray Wolf in the Southwestern United States

Gray wolves were once abundant and widespread in North America; presettlement, the gray wolf ranged from the Canadian high arctic through the United States to central Mexico (Wayne and Vilá 2003, Mech 1970). Prior to the late 1800s, gray wolves ranged across the landscape of the southwestern United States in montane forests and woodlands (Young and Goldman 1944). Mexican wolves were abundant in the Sierra Madre and outlying mountain ranges in Mexico, and frequented the borderlands between Mexico and the United States (Brown 1983). In southern Arizona, Mexican wolves inhabited the Santa Rita, Tumacacori, Atascosa-Pajarito, Patagonia, Chiricahua, Huachuca, Pinaleno, and Catalina mountains, west to the Baboquivaris and east into New Mexico (Brown 1983). In central and northern Arizona, Mexican wolves and several other formerly recognized subspecies of gray wolf were interspersed (Brown 1983). Mexican wolves and up to four formerly recognized subspecies were present throughout New Mexico, with the exception of low desert areas, and were documented as numerous or persisting in areas including the Mogollon, Elk, Tularosa, Diablo and Pinos Altos mountains, the Black Range, Datil, Gallinas, San Mateo, Mount Taylor, Animas, and Sacramento mountains (Brown 1983). The gray wolf was found eastward into the Trans-Pecos region of Texas, Oklahoma, and northward into the Rocky Mountains, including the states of Montana, Idaho, Wyoming, and Colorado (Young and Goldman 1944). In Colorado, gray wolves inhabited both sides of the Continental Divide, including the eastern plains (Young and Goldman 1944). In Utah, gray wolves were restricted to the southern and eastern portions of the state.

Population estimates of gray wolves, and specifically Mexican wolves, prior to control actions in the late 1800s and early to mid 1900s are not available for the Southwest or Mexico. This is due primarily to a lack of available data on wolf abundance, but also to difficulty in interpreting anecdotal accounts of wolf abundance in light of evolving gray wolf taxonomy (see Taxonomy and Range). Anecdotal pre-colonization estimates for New Mexico suggested a state-wide population of about 1500 gray wolves (Bednarz 1988). It has been hypothesized that close to 400,000 gray wolves likely inhabited the western United States (Leonard et al. 2005).

As human settlement intensified across the Southwest in the 1800s, the conflict between wolves and humans, primarily due to wolf depredation of livestock, also intensified. Individual wolves gained infamy for purported levels of depredation, although the validity of some of these accounts is questionable (Gipson et al. 1998, Gipson and Ballard 1998). Federal control programs and extermination campaigns, coupled with habitat alteration resulting from the intensification of agriculture and livestock operations, led to the near extinction of the gray wolf in the Southwest by the early 1900s (Brown 1983). By 1925, poisoning, hunting, and trapping efforts had drastically reduced wolf populations in all but a few remote areas of the southwestern United States, and control efforts shifted to wolves in the borderlands between the United States and Mexico (Brown 1983). Bednarz (1988) estimated that breeding populations of Mexican wolves were extirpated from the United States by 1942. The use of increasingly effective poisons and trapping techniques during the

1950s and 1960s eliminated remaining wolves north of the border. Occasional reports of wolves crossing into the United States from Mexico persisted to the 1960s, and small pockets of wolves likely persisted in Mexico until the 1980s. McBride (1980) estimated that fewer than fifty breeding pairs of Mexican wolves inhabited Mexico by 1978.

The Road to Recovery

With the passage of the ESA, the legal relationship of the Service to the gray wolf changed dramatically. Formerly a proponent of efforts to exterminate the wolf, the agency became responsible for the conservation and recovery of species protected by the ESA, including the gray wolf. The Service originally added the Mexican wolf to the list of threatened and endangered species as a subspecies (41 FR 17736-17740, April 28, 1976), but soon subsumed this and several other gray wolf subspecies listings into a species-level listing for the gray wolf in order to protect the species throughout its range in the coterminous United States and Mexico (43 FR 9607-9615, March 9, 1978). This reclassification provided a commitment that the Service would maintain a conservation focus on recognized gray wolf subspecies in the future although it simultaneously recognized that some of the gray wolf taxonomy used in previous subspecies listings was out of date.

Soon after the range-wide listing of the gray wolf in 1978, the Service initiated several independent regional recovery programs to recover the gray wolf. These recovery programs were centered in three core geographic areas: Minnesota, Michigan, and Minnesota ("Great Lakes", administered by the Service's Great Lakes, Big Rivers Region); Idaho, Montana, and Wyoming ("Northern Rockies", administered by the Service's Mountain-Prairie Region and Pacific Region); and Arizona and New Mexico, with coordination with Mexico (administered by the Service's Southwest Region). Recovery plans were developed by the three recovery programs to organize and prioritize recovery actions appropriate to the unique circumstances of the gray wolf in each area. The Mexican Wolf Recovery Plan was finalized in 1982, solidifying the focus of gray wolf recovery efforts in the southwestern United States on the Mexican wolf subspecies (USFWS 1982). The recovery plan was binational, signed by the Service in the United States and the Dirección General de la Fauna Silvestre in Mexico.

The development of the 1982 Mexican Wolf Recovery Plan marked the beginning of a 2-pronged approach to recovery that included establishment of a captive breeding program and reintroduction of Mexican wolves to the wild. The prime objective of the 1982 recovery plan was to "conserve and ensure and survival of *Canis lupus baileyi* by maintaining a captive breeding program and re-establishing a viable, self-sustaining population of at least 100 Mexican wolves in the middle to high elevations of a 5,000-square-mile area within the Mexican wolf's historic range (USFWS 1982:23)." This "prime objective" of the recovery plan was not considered an objective and measurable recovery criterion for delisting as required by section 4(f)(1) of the ESA, but instead was a recommendation to ensure the immediate survival of the Mexican wolf. The recovery team could not foresee full recovery and eventual delisting of the Mexican wolf due to its dire status in the wild and the increasing encroachment of humans into wolf habitat, and therefore stopped short of providing recovery criteria.

A captive breeding program, founded by three of the last six Mexican wolves removed from the wild, was underway at this time in the United States, with the first pups born in captivity in 1981 (Parsons 1996, Hedrick et al. 1997, Lindsey and Siminski 2007). In 1987, several facilities in Mexico joined the captive breeding effort (SEMARNAP 2000). By 1994, breeding of the three founding wolves and their offspring (initially referred to as the Certified lineage, later as the McBride lineage) had resulted in a captive population of 92 wolves. However, concern began to surface over the limited genetic diversity of the captive population and the potential for inbreeding depression to hinder its success (Parsons 1996, Hedrick et al. 1997). Thus, in 1995, after definitive genetic testing methods became available and were applied, two additional lineages of pure Mexican wolves, the Ghost Ranch lineage, founded by two wolves, and the Aragon lineage, founded by two wolves, were integrated into the captive breeding program to increase the genetic diversity of the founder population. This raised the founding base of the captive population from three to seven pure Mexican wolves (Hedrick et al. 1997). The Association of Zoos and Aquariums (AZA) developed a Species Survival Program (SSP) for the captive population to establish breeding protocols and genetic goals to guide wolf pairings, with the ultimate objective of providing healthy offspring for release to the wild (Parsons 1996, Lindsey and Siminski 2007).

In 1994, Mexico formally recognized the Mexican wolf as an endangered subspecies under the Norma Oficial Mexicana NOM-059-ECOL-1994, a Mexican Federal law protecting wildlife, followed by development of a recovery plan for the Mexican wolf, Programa de Recuperación del Lobo Mexicano, in 1999 (SEMARNAP 2000). Mexico's recovery plan supported reintroduction on both sides of the Mexico-United States border, but stated that it would be difficult to find appropriate habitat for reintroduction in Mexico and suggested that the best habitat may exist within the Sierra Madre Occidental and the Sierra Madre Oriental mountain ranges (SEMARNAP 2000).

Plans for the reintroduction of the Mexican wolf in the southwestern United States began to develop in the mid-1990s, stimulated in part by a suit filed against Service by seven environmental organizations for failure to implement provisions of the ESA (Wolf Action Group, et al. vs. United States, Civil Action CIV-90-0390-HB, U.S. District Court, New Mexico). During this time, the Service formed a new recovery team to revise the 1982 Mexican Wolf Recovery Plan with updated scientific information and recovery criteria. The draft recovery plan developed by the new recovery team was not finalized, and the prime objective of the 1982 recovery plan to establish a population of at least 100 wolves in the wild was maintained as a guiding recommendation for the upcoming reintroduction. Several analyses were conducted to assess locations for the reintroduction (Johnson et al. 1992, USFWS 1993), culminating with the Final Environmental Impact Statement, "Reintroduction of the Mexican Wolf within its Historic Range in the Southwestern United States," (FEIS) (USFWS 1996). By 1998, the plans for the reintroduction were solidified in the final rule, "Establishment of a Nonessential Experimental Population of the Mexican Gray Wolf in Arizona and New Mexico" (Final Rule) (63 FR 1752-1772, January 12, 1998), and in March of that year, 11 Mexican wolves from the captive breeding program were released to the wild. The Mexican wolf was one of only three carnivores (the Mexican wolf, the blackfooted ferret (*Mustela nigripes*), and red wolf (*Canis rufus*)) in North America to have been eliminated in the wild, bred in captivity, and reintroduced to the wild (Brown and Parsons 2001).

The Final Rule established the Mexican Wolf Experimental Population Area (MWEPA) in central Arizona and New Mexico, which designated the reintroduction effort as a non-essential experimental population under section 10(j) of the ESA (Figure 1). This designation was made because wolves released to the wild would represent excess genetic material produced from the captive breeding program and because it allowed for regulatory flexibility in managing released wolves and their progeny, an important consideration at the time for public support of the reintroduction (Brown and Parsons 2001; 63 FR 1752-1772, January 12, 1998). The entire MWEPA was not considered reintroduction and recovery habitat for the Mexican wolf, but rather much of the MWEPA provided a transition zone between the Blue Range Wolf Recovery Area (BRWRA) designated within the MWEPA and the endangered designation of the surrounding landscape (i.e., wolves outside of the MWEPA have full endangered status under the classification provided by the 1978 gray wolf listing) (63 FR 1752-1772, January 12, 1998). The rule stipulated that the reintroduction of wolves would take place within the BRWRA, a 17,775 km^2 (6,845 mi^2) area that included the Apache National Forest in east-central Arizona and the Gila National Forest in west-central New Mexico. Within the BRWRA, a Primary Recovery Zone in the Apache National Forest was designated for release (initial release and translocation) of Mexican wolves, with a Secondary Recovery Zone in the Gila National Forest providing dispersal habitat for released wolves (Figure 1). The Final Rule defined a Secondary Recovery Zone as "…an area adjacent to a primary recovery zone in which the Service allows released wolves to disperse, where wolves captured in the wild for authorized management purposes may be translocated and released, and where managers will actively support recovery of the reintroduced population" (63 FR 1752-1772, January 12, 1998). The FEIS, however, made no specific analysis of translocating wolves into the Secondary Recovery Zone (USFWS 1996). The Service prepared an environmental assessment in 2000, analyzing translocation of wolves into the Secondary Recovery Zone. This analysis determined that such translocation of wolves into the Secondary Recovery Zone of the BRWRA would not create significant new impacts beyond those analyzed in the EIS (USFWS 2000). The strategy for the reintroduction was to release 14 family groups of wolves over a period of 5 years in order to establish the population (63 FR 1752-1772, January 12, 1998). The FEIS projected that the population target of at least 100 wild wolves would be reached in nine years (USFWS 1996).

Today, the Mexican Wolf Blue Range Reintroduction Project (reintroduction project) is an interagency effort governed by a Memorandum of Understanding that assigns state and tribal leadership of the reintroduction to the Arizona Game and Fish Department (AGFD), New Mexico Department of Game and Fish (NMDGF), and the White Mountain Apache Tribe (WMAT) (see AMOC and IFT 2005: AC-Appendix 2). Together with the Service, U.S. Department of Agriculture-Animal and Plant Health Inspection Service Wildlife Services (USDA-WS), and U.S. Department of Agriculture Forest Service (USFS), these lead agencies have primary regulatory jurisdiction and management authority of the Mexican wolf in Arizona and New Mexico. Graham, Greenlee, and Navajo counties in Arizona, and Catron and Sierra counties in New Mexico, as well as the New Mexico Department of

Agriculture, are designated as cooperators to the reintroduction project with an interest in Mexican wolf management. The adjoining Fort Apache Indian Reservation (FAIR) tribal lands of the WMAT provide an additional 6,475 km^2 (2,500 mi^2) for direct release of wolves, pursuant to an agreement signed between Service and WMAT in 2002. ("Blue Range population" refers to wolves in the BRWRA, as well as those on FAIR and surrounding lands).

Turner Endangered Species Fund and Wolf Haven International support the reintroduction project by providing pre-release captive facilities where wolves from the captive breeding program are acclimated prior to release to the wild. The Defenders of Wildlife administers a compensation trust that provides economic compensation to ranchers for wolf depredation of cattle, sheep, and other livestock. The AZA SSP captive breeding program, which has expanded to 47 facilities and has received national commendation for its commitment to the conservation of the Mexican wolf (AZA 2008), continues to support the reintroduction by producing wolves for release to the wild and conducting research.

On a daily basis, management of the wolf reintroduction project may include wolf releases and translocations, monitoring, depredation response, outreach and education, research and information collecting, and other fieldwork (Brown and Parsons 2001). An Interagency Field Team (IFT), consisting of field staff from the six lead agencies, carries out the majority of the daily on-the-ground activities, with oversight and planning carried out by AMOC, a committee of management-level staff from the six lead agencies.

As of December 2007 the Blue Range wolf population consisted of approximately 52 wolves and a minimum of 4 breeding pairs (USFWS 2008: Population Statistics). Although the population has grown steadily since 1998 from both the direct release of wolves and natural reproduction (AMOC and IFT: TC-11), the population target of at least 100 wolves has not been reached. The highest annual minimum population count since 1998 was 59 wolves (minimum of 7 breeding pairs) in 2006, the year in which the FEIS predicted the population target would be met USFWS 2008: Population Statistics).

One of the initial hypotheses for the moderate progress of the reintroduction was the reliance on naïve, captive wolves (Brown and Parsons 2001), which had been considered one of the biggest possible impediments to successful reintroduction (Brown 1983). In this regard, the Mexican wolf reintroduction is more similar to the Service red wolf reintroduction and recovery program in the eastern United States than to the Service gray wolf programs in the Northern Rockies and Great Lakes, both of which relied on translocation of wild wolves, natural population growth, and/or natural recolonization from wolf dispersal from adjacent wolf populations rather than captive-bred wolves. Specifically, it has been hypothesized that naïve Mexican wolves may be less capable of exploiting prey and therefore have fewer surviving pups than other gray wolf populations (AMOC and IFT 2005: TC-17-18), with data suggesting that the success (breeding and production of pups after release to the wild) of Mexican wolves in the wild may be positively influenced when the greater proportion of its life is spent in the wild. Success of Mexican wolves has been more comparable to the success of red wolves than the Northern Rockies gray wolves (AMOC and IFT 2005: TC-18).

In addition to the potential implications of using naïve, captive wolves to establish a reintroduction project, two biological evaluations of the Mexican wolf reintroduction project have suggested that regulatory mechanisms may also be contributing to the moderate growth of the population (Paquet et al. 2001, AMOC and IFT 2005, and see Threats to the Gray Wolf in the Southwest, below). These evaluations were conducted pursuant to the Final Rule, which stipulated that the progress of the reintroduction be assessed 3 years and 5 years after its inception to determine whether the reintroduction should continue, and if so, whether it should be modified in any way (63 FR 1752-1772, January 12, 1998). Both reviews also included extensive socio-economic components (Kelly et al. 2001, Unsworth et al. 2005).

The 3-Year Review, which included a technical component and a stakeholder's component, assessed the progress of the reintroduction from its inception to 2001. The technical component of the 3-Year Review, commonly referred to as the Paquet Report, was conducted by four independent (non-agency) gray wolf experts. They analyzed the establishment of home ranges in the recovery area, wild reproduction, wolf mortality levels, wolf population growth, prey adequacy, livestock depredation control, and threats to human safety. They concluded that the project was proceeding reasonably well from a biological standpoint and that continued application of existing management would eventually result in the establishment of a wild, self-sustaining population of wolves. Lower than predicted survival rates and reproduction levels, however, would likely result in slower progress in achieving population targets than estimated during the planning of the reintroduction. They further concluded that several factors were ultimately hindering the biological success of the project: 1) the small size of the primary recovery zone, which limited the establishment phase of the project; 2) the requirement that wolves stay within the BRWRA, which did not allow for natural dispersal movements; and, 3) the Service's objective to establish a population of at least 100 wolves, which was not deemed an adequate size for long-term viability (Paquet et al. 2001:60-61). To address these issues, they recommended that the Service initiate a recovery team to revise the 1982 Mexican Wolf Recovery Plan and modify the Final Rule to allow initial releases into the Gila National Forest and allow wolves to establish territories outside of the BRWRA. They also made several additional recommendations relating to management, outreach, and education to improve the efficacy of the project.

In the few years between the 3- and 5-Year reviews, the Service and its State, Federal, and tribal partners sought to implement the recommendations of the 3-Year Review. However, due to a variety of circumstances that are detailed in the 5-Year Review, many of the recommendations were not implemented, or not to the degree desired and expected by interested parties (AMOC and IFT 2005: AC). The purpose of the 5-Year Review was again to evaluate the progress of all aspects of the reintroduction, this time from 1998 to 2003 (some aspects of the project were analyzed through 2005), specifically providing follow-up to questions identified in the 1998 Mexican Wolf Interagency Management Plan (Parsons 1998), recommendations from the 3-Year Review, recommendations from the Arizona-New Mexico independent review of the 3-Year Review that was directed by Congress (AGFD and NMDGF 2002), "Commission Directives" to the State Wildlife Agencies of Arizona and New Mexico and NM (see AMOC and IFT 2005, Attachment 1), and public comments received during the 5-Year Review process in 2005.

The 5-Year Review was conducted by AMOC, the IFT, and a socioeconomic consulting firm, and incorporated extensive public input. In the Technical Component of the Review, which addressed the biological progress of the project, AMOC concluded that progress toward establishment of a population of at least 100 wolves was generally proceeding in line with projections from the FEIS. However, they also recognized that guidelines in the Final Rule that require removal of wolves that establish home ranges outside of the recovery BRWRA or at landowners request are contrary to normal wolf movements and are resulting in higher levels of wolf releases and removals than projected in the FEIS. Further, they found that wolves spending a greater proportion of their lives in the wild are more likely to be successful, and therefore wolves ought to be translocated, rather than permanently removed, after their first removal event except in extreme situations (AMOC and IFT: TC-24).

The 5-Year Review culminated with a list of 37 recommendations. Fourteen of the recommendations addressed the need for further analysis of potential modification of the MWEPA, including expansion of external boundaries, expansion of a recovery zone designated for release of wolves, additional provisions for harassment and take of wolves, creation of an incentives program to mitigate wolf nuisance and livestock issues, analysis of social and economic impacts associated with any MWEPA modifications under consideration, and provisions for another review of the reintroduction project in 2009-2010. The remaining recommendations dealt with management issues related to information gathering, techniques, and public access to data; ongoing advisory needs; annual planning, including staffing, training, and budgeting; field techniques; law enforcement; outreach, public involvement, and education; and private property incentives (AMOC and IFT: ARC).

Following the completion of the 5-Year Review in 2005, the Service determined that the reintroduction should continue, and agreed that modifications to the Final Rule may be necessary (USFWS 2006b). Since that time, the lead agencies have acknowledged that the population is lagging behind the projections of the FEIS (USFWS 2005:27) and that management action is needed to support population growth (AGFD 2007: 13). Recently, the Service conducted a public scoping process to seek additional public input on possible modifications to the reintroduction project that will address biological, social, and economic issues related to its progress (72 FR 44065-44069, August 7, 2007). Analysis of these comments is currently underway (USFWS 2008: Rule Modification).

Summary statement: A two-pronged gray wolf recovery effort in the Southwest includes an international network of Mexican wolf captive breeding facilities and an interagency Mexican wolf reintroduction project in Arizona and New Mexico.

Summary statement: Following completion of the 5-Year Program Review in 2005, the Service determined that reintroduction should continue, and agreed that modification to the Final Rule may be necessary.

Summary statement: Progress in achieving the Mexican wolf population target of at least 100 wolves in the BRWRA has fallen short of initial expectations by several years, likely due to a combination of biological and regulatory factors.

Status and Implications of National Gray Wolf Recovery for the Mexican Wolf

It is reasonable to expect that the progress of gray wolf recovery efforts in the Great Lakes, Northern Rockies, and Southwest would differ due to the variety of circumstances and policy decisions affecting each program. In both the Great Lakes and Northern Rockies, the gray wolf has rebounded rapidly in the wild due to a combination of factors, including the reintroduction of wild wolves from Canada into the Northern Rockies, natural population growth, and natural recolonization by wolves from nearby populations. Both programs have been guided by recovery plans with recovery criteria that were revised and refined over time as relevant new information was gathered (see USFWS 1987 and 72 FR 6051-6103, February 8, 2007, for the Great Lakes, and USFWS 1992 and 73 FR 10514-10560, February 27, 2008, for the Northern Rockies). In the Great Lakes, a population of over 3,000 wolves inhabits Minnesota, with a second population of close to 1,000 wolves inhabiting the two-state area of Michigan and Wisconsin (72 FR 6051-6103, February 8, 2007). Prior to listing, wolves had been effectively exterminated from Wisconsin and Michigan, with the exception of a small population on Isle Royale, and less than 1,000 wolves inhabited Minnesota (72 FR 6051-6103, February 8, 2007). With the protections of the ESA in the late 1970's, gray wolves began to rebound in abundance and distribution. Today, population growth in the three-state area has leveled off, and these populations maintain connectivity to healthy gray wolf populations in Manitoba (~4,000 wolves) and Ontario (~8,000 wolves), Canada (72 FR 6051-6103, February 8, 2007).

In the Northern Rockies, a population of over 1,500 gray wolves inhabits core recovery areas in Montana, Idaho, and Wyoming (USFWS et al. 2008). Gray wolves had also been decimated in these states prior to protection under the ESA. In the mid 1980s, natural reproduction was documented in a small population of wolves that had dispersed to northwestern Montana from Canada; this population continued to grow to its current size of around 200 wolves. In central Idaho and the Greater Yellowstone Area (which includes portions of Idaho, Montana, and Wyoming surrounding Yellowstone National Park), gray wolves were reintroduced from Canada in the mid-1990s into nonessential experimental populations (59 FR 60266-60281, November 22, 1994; 59 FR 60252). In 2008, the Yellowstone population was estimated at close to 200 wolves, and the Idaho population was close to 900. Routine dispersal has been documented between the northwestern Montana population, Idaho population, and Canadian populations (73 FR 10514-10560, February 27, 2008).

In the Great Lakes and Northern Rockies, the Service determined that the gray wolf is recovered, and reclassified and delisted these portions of the species' range as distinct population segments (DPS) in 2007-2008 (72 FR 6051-6103, February 8, 2007; 73 FR 10513-10560, February 27, 2008). However these designations and delistings were reversed in legal challenge against each (Humane Society of the United States, et al. v. Kempthorne, et al., Civil No. 1:07-cv-00677-PLF (D. D.C.), Defenders of Wildlife, et al. v. Hall, et al., Civil No. 9:08-cv-00056-DWM (D. Mont.)). While the Service will attempt to address the legal issues in future delisting rules for these populations, as of this writing, gray wolves remain threatened in the Great Lakes and endangered throughout the rest of the coterminous United States, except where designated as nonessential experimental populations.

The ongoing struggle between the Service's delisting actions and related legal challenges in the Great Lakes and Northern Rockies has been ongoing for several years and has delayed efforts to develop an up-to-date gray wolf recovery plan in the Southwest to replace the 1982 Mexican Wolf Recovery Plan. In 2003, the Service reclassified the gray wolf into three distinct population segments in order to divide the gray wolf's listed range from the 1978 listing (the coterminous United States and Mexico) into three separate entities for which policy action, such as delisting, could be pursued for each independent of the others (68 FR 15804-15875, April 1, 2003; and see "Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act", 61 FR 4721-4725, February 7, 1996). Specifically, the Service wanted to recognize the progress made toward recovery of the gray wolf in the Great Lakes and Northern Rockies but concurrently recognized that commensurate progress toward recovery had not been made in the gray wolf recovery program in the Southwest (68 FR 15804-15875:15811, April 1, 2003). Thus, under the 1978 gray wolf listing, neither range-wide downlisting of the gray wolf from endangered to threatened nor range-wide delisting could be pursued due to the imbalance of recovery achieved between the regional programs.

Soon after the 2003 reclassification, the Southwest Region of the Service convened a recovery team to develop a recovery plan and recovery criteria for the newly designated Southwestern Distinct Population Segment (SWDPS), which included the southern portions of Utah and Colorado, western portions of Oklahoma and Texas, all of Arizona and New Mexico, and the wolf's historic range in Mexico. The recovery planning effort was intended to provide a regional gray wolf recovery plan that would supercede the 1982 Mexican Wolf Recovery Plan and provide context for the Blue Range reintroduction in terms of the wolf abundance and distribution necessary for recovery in the Southwest. However, the 2003 reclassification rule was vacated and remanded to the Service in 2005 (see Defenders of Wildlife v. Norton, 03-1348-JO; National Wildlife Federation v. Norton, 1:03-CV-340, D. VT. 2005). As a result of this litigation, which invalidated the team's charge to develop a plan for the SWDPS because the SWDPS was no longer a listed entity, the Service put the recovery planning process on hold while the agency determined how to respond. The planning effort has not been resumed, and the Southwest Region remains without the guidance of an up-to-date gray wolf recovery plan, specifically as it relates to the future of the subspecific Mexican wolf reintroduction and recovery effort currently underway. Meanwhile, the DPSs for the Great Lakes and Northern Rockies have been redesignated and delisted later to be overturned in litigation.

If future reclassification and delisting of the gray wolf distinct population segments in the Northern Rockies and Great Lakes are successful, the species will remain delisted in these areas but listed as endangered in all or portions of 42 states based on the remaining gray wolf range designated in the 1978 listing. Thus, gray wolves dispersing from delisted areas may travel into areas designated as endangered, where they receive the full protections of the ESA. However, other than the potential for small numbers of dispersals from delisted areas into areas designated as endangered, gray wolves do not currently inhabit any of the remaining listed states in substantial number other than Arizona and New Mexico, where the Mexican wolf nonessential experimental population reintroduction is conducted. The gray wolf recovery program in the Southwest is the only remaining of the original three, and the agency has not indicated whether additional gray wolf recovery efforts will be pursued in other regions of the country.

Summary statement: A shifting policy landscape for gray wolf recovery and recovery planning in the Southwest continues to be created by the fluctuating status of gray wolf recovery and delisting actions in the Northern Rockies and Great Lakes.

Summary statement: The gray wolf recovery program in the Southwest operates in absence of an up-to-date recovery plan that contains recovery criteria and conservation actions that would situate the BRWRA population as an integral component of regional and national gray wolf recovery.

State and International Regulatory Protection in the Southwestern United States and Mexico

In addition to its listed status under the ESA, the gray wolf is also protected under State wildlife statutes in the Southwest and Mexico. The gray wolf is classified as endangered in Arizona (Wildlife of Special Concern/Threatened native wildlife in Arizona, and listed as endangered in New Mexico (Wildlife Conservation Act, 17-2-37 through 17-2-46 NMSA 1978) and Texas (Texas Statute 31 T.A.P). Wolves are considered "protected wildlife" in Utah; they cannot be harvested unless the Wildlife Board establishes an open season for harvest (Utah Code Annotated, Title 23). The gray wolf is not included on Utah's Sensitive Species List, as the species is not considered resident in Utah at this time and because the ESA provides protection. Wolves are listed as endangered by Colorado (Colorado Revised Statues 33-2-105, "Nongame, Endangered, or Threatened Species Conservation Act", Title 33. In Mexico, the Mexican wolf subspecies continues to be protected under the Ley de Vida Silvestre (2000), Norma Oficial Mexicana NOM-059-ECOL-2001 (2002). The gray wolf is not listed or protected by State law in Oklahoma.

GRAY WOLF BIOLOGY AND ECOLOGY

Taxonomy and Range

The gray wolf, *Canis lupus*, is a member of the dog family *(Canidae; Order Carnivora).* The genus *Canis* also includes the red wolf (*C. rufus*), dog (*C. familiaris*), coyote (*C. latrans*), several species of jackal (*C. aureus*, *C. mesomelas*, *C. adustus*) and the dingo (*C. dingo*) (Mech 1970). Type localities of previously recognized subspecies are documented in Young and Goldman (1944); the type locality of *Canis lupus baileyi* Nelson and Goldman is Colonia Garcia, Chihuahua, Mexico.

It is likely that, with the possible exception of the wolf of southeastern Canada and northeastern United States (Wilson et al. 2003), all gray wolves evolved from the small, early canids that were widespread in North America and the Old World during the Pliocene, some 2 to 4.5 million years ago (Nowak 2003). The gray wolf likely evolved in Eurasia from wolves that crossed into Eurasia from North America. A branch of these wolves (that is, *Canis lupus*) then reinvaded the New World during the middle Pleistocene (around 300,000 years ago), via the Bering Strait land bridge (Wayne et al. 1992, Nowak 1995, Nowak 2003: Table 9.2, Brewster and Fritts 1995, Parsons 1996). It is hypothesized that waves of gray wolf migration likely occurred in response to changing glacial ice patterns and openings in the Bering Sea (Nowak 1995, Nowak 2003, Wayne and Vilá 2003). Once in the New World, wolves dispersed southward and eastward, gradually spreading across the continent (Nowak 2003, Parsons 1996).

Twenty-four subspecies of gray wolf have been described in North America (Hall and Kelson 1959). Five of these subspecies occurred in the southwestern United States and Mexico: *C. l. baileyi, C. l. mogollonensis, C. l. monstrabilis, C. l. nubilus, and C. l. youngi*. Hall (1981) described *C.l. baileyi's* range as including only a small portion of extreme southwestern New Mexico and southeastern Arizona. However, a taxonomic revision proposed by Bogan and Mehlhop (1980, 1983) lumped *C. l. mogollonensis* and *C. l. monstrabilis* with *C. l. baileyi*, thereby extending *C.l. baileyi's* range to northern Arizona and central New Mexico, and recognizing only three southwestern subspecies, *C.l. baileyi*, *C.l. youngi*, and *C.l. nubilis*. The Service adopted the findings of Bogan and Mehlhop in the 1982 Mexican Wolf Recovery Plan, thus supporting reintroduction of *C.l. baileyi* north of *C.l. baileyi's* range as originally conceived by Young and Goldman (1944) and Hall and Kelson (1959).

In a subsequent reclassification of North American gray wolves, Nowak (1995) proposed reduction of the number of recognized subspecies from 24 to 5, recognizing *C.l. arctos, C.l. baileyi, C.l. lycaon, C.l. nubilus,* and *C.l. occidentalis* as subspecies. In this classification, *C. l. baileyi* was recognized as a subspecies, but *C. l. mogollonensis* and *C. l. monstrabilis* were grouped with *C. l. nubilus*. The classifications proposed by Hall and Kelson (1959), Bogan and Mehlhop (1983), and Nowak (1995) were based on comparisons of morphological characteristics, primarily skull measurements. Parsons (1996) added knowledge of dispersal patterns to the historic range of *C.l. baileyi* proposed by Nowak (1995) and concluded that historically Mexican wolves ranged as far north as central New Mexico and east-central

Arizona. The Service adopted the historic range proposed by Parsons (1996) for *C.l. baileyi*, a 200-mile northward extension of Nowak's range for *C.l. baileyi*, and included it in the FEIS (USFWS 1996).

This history highlights the disagreement in North America over the use of sub-specific nomenclature to describe geographic variation among gray wolf populations across their historically vast range (Brewster and Fritts 1995, Nowak 2003). As Brewster and Fritts (1995:355) explained, "Inherent in most recent thinking [of subspecies definition] is the idea that members of a subspecies should be more closely related to one another than to individuals of another subspecies, and further, that geographic or ecological isolation (e.g., islands, mountain ranges separated by deserts, plains separated by mountain ranges) has caused gene flow between populations to be restricted and allowed differentiation of characteristics." Difficulty in grouping wolves into subspecies arises due to the tendency of gray wolves to move significant distances across the landscape: during these movements, dispersing wolves may come into contact with near or distant wolf populations, potentially resulting in high rates of gene flow between populations and limited genetic differentiation among populations (Wayne et al. 1992, Roy et al. 1994, Vilá et al. 1999).

Wolves' dispersal behavior led to the conclusion that wolves existed historically in intergradations across the North American landscape (Young and Goldman 1944, Mech 1970, Brewster and Fritts 1995, Leonard et al. 2005). Mech (1970:30) commented that, "Wherever subspecies meet, their characters tend to blend as a result of interbreeding, or intergradation…". Under optimal conditions wolves' dispersal capabilities exceed 500 miles (Fritts 1983, Boyd et al. 1995), thus these zones of subspecies intergradation were likely hundreds of miles wide (Brewster and Fritts 1995). Given this information, the difficulty in describing where one subspecies' boundary begins and ends becomes apparent. As Wayne and Vilá (2003:223) recently stated, "the division of wolves into discrete subspecies and other genetic units may be somewhat arbitrary and overly typological (conforming to a specific ideal type). In reality, wolves are better viewed as a series of intergrading populations having subtle or undetectable patterns of clinal [continuous gradation in any trait] genetic change."

In recent decades, the emergence of the field of conservation genetics has contributed significantly to understanding the gray wolf. Recent molecular genetic evidence indicates that there was considerable gene flow across the subspecies' boundaries postulated by Nowak (1995, 2003) (Leonard et al. 2004), in keeping with the previous understanding that wolves naturally existed in intergradations across the landscape. More specifically, there is evidence of gene flow across the recognized boundary of *C.l. baileyi*; analyses of historic specimens demonstrate that the gray wolves that inhabited northern Arizona, southern and central Utah, northern New Mexico, and southern and central Colorado had genetic markers now associated with the Mexican wolf. In other words, Mexican wolves likely intergraded with other gray wolves at the northern extent of their range. This intergradation of northern and Mexican wolf-related haplotypes has recently been conceptualized as a southern clade (i.e., group that originated from and includes all descendents from a common ancestor) (Leonard et al. 2005). This research has also shown that there are some genetic markers more typical of Canadian and Alaskan wolves in Mexican wolves, providing evidence of some historical contact between Mexican wolves and northern subspecies (Leonard et al. 2004).

Based on genetic analyses, it has also been determined that the genetic makeup, or genotype, of all gray wolves is very similar (Wayne et al. 1992). Mitochondrial DNA analysis has suggested that, with a few exceptions, a genetic basis for the previous sub-specific designations of gray wolf may not exist (Wayne et al. 1995). Molecular genetic analyses, however, provide indisputable evidence that the Mexican wolf has distinct genetic attributes differing by 2.2 percent from other North American gray wolves (Wayne and Vilá 2003), thus supporting earlier morphological characterization of the Mexican wolf as a distinct subspecies (García-Moreno et al. 1996, Hedrick et al. 1997, Wayne et al. 1992, and see Nowak 2003).

The origins of the distinct genetic traits and morphological features of the Mexican wolf are uncertain, but it is hypothesized that *C.l. baileyi* represents one of the earliest waves of migration of the gray wolf onto the continent (Wayne and Vilá 2003) after which *C.l. baileyi* may have experienced random genetic drift during a period of isolation from other wolf populations as expansion and retraction of glacial ice patterns caused ephemeral boundaries to dispersal and continent-wide population flux in gray wolf abundance (Vilá et al. 1999, Roy et al. 1994, Wayne et al. 1995). Another possible explanation is based on the knowledge that morphological differences are not necessarily indicative of long periods of geographic isolation and may only indicate intense natural selection on particular physical features (Wayne et al. 1992). Geographic variations in body size and pelage, therefore, could be a result of selection for differences in habitat or prey type, resulting in differentiation despite otherwise high levels of gene flow (Wayne et al. 2004). There is no scientific certainty whether drift or selection caused *C.l. baileyi's* distinctiveness.

Summary statement: Integration of ecological, morphological, and genetic evidence supports several conclusions relevant to the southwestern United States regarding gray wolf taxonomy and range. First, there is agreement that the Mexican wolf is distinguishable from other gray wolves based on morphological and genetic evidence. Second, recent genetic evidence continues to support the observation that historic gray wolf populations existed in intergradations across the landscape due to gene flow as a result of their dispersal ability. Third, evidence suggests that the southwestern United States (southern Colorado and Utah, Arizona and New Mexico) included multiple wolf populations distributed across a zone of intergradation and interbreeding, although only *C.l. baileyi* inhabited the southernmost extent.

Physical Description and Life History

Gray wolves often vary considerably in size, although males typically weigh between 36-55 kg (80-120 lbs), are 1.5 to 2 m (5-6.5 ft) long from tip of nose to tip of tail, and 66 to 81 cm (26-32 in) high at the shoulder. Males are typically 15-20 percent larger than females in weight and length. Gray wolves exhibit significant variety in pelt color: the most commonly observed pelt is a mottled charcoal gray, but pelt color can range from white, cream, brown and red, to dark gray and black (Mech 1970). Individual wolves may exhibit any or all of these colors (Fuller 2004).

The Mexican wolf (Figure 2) is the smallest extant gray wolf in North America; adults weigh 23-41 kg (50-90 lbs) with a length of 1.5-1.8 m (5-6 ft) and height at shoulder of 63-81 cm (25-32 in) (Young and Goldman 1944, Brown 1983). Mexican wolves are typically a patchy black, brown to cinnamon, and cream color, with primarily light underparts (Brown 1983); solid black or white Mexican wolves do not exist as seen in other North American gray wolves (USFWS 2008).

Basic descriptive life history information is well documented for gray wolves, although less so for the Mexican wolf. In the wild, wolves typically live 4 to 5 years, although they can reach 13 years (Mech 1988). They reach sexual maturity at 2 years of age (Mech 1970). Wolves have one reproductive cycle per year, and females are capable of producing a litter of pups, usually four to six, each year (Mech 1970). Litters are born in spring in a den or burrow that the pack digs (Mech 1970, Packard 2003). Pups weigh about 1 lb (0.5 kg) at birth (Mech 1991), and remain inside the den for at least 4 weeks, during which time their eyes open and the animals learn to walk (Packard 2003). Pup mortality during the denning period is difficult to document due to lack of access to den sites (Fuller et al. 2003).

In the Blue Range population, Mexican wolf pups are generally born between early April and early May (AMOC and IFT 2005: TC-6). Average litter size (2.1 pups) following the denning period is smaller than Mexican wolf litters in captivity (4.6 pups/litter) (AMOC and IFT: TC-17), gray wolf litters elsewhere (AMOC and IFT: TC-12, see Fuller et al. 2003), or the historical litter sizes of wild Mexican wolves reported by McBride (4.5 pups) (1980), but is similar to red wolf litter sizes (2.8 pups/litter) (Phillips et al. 2003). Several hypotheses to explain the small litter sizes in Blue Range population have been suggested: 1) wolves may be limited by the amount of vulnerable prey due to winter snow patterns; 2) litter sizes may be a historical adaptation to the environment; or, 3) wolves released from captivity may be less capable of exploiting vulnerable prey, potentially further affected by frequent management that decreases their ability to fully exploit their home ranges (AMOC and IFT: TC-18). Moreover, it is likely that more Mexican wolf pups are born than are observed in the wild when counts are conducted, but actual litter size at birth and early pup mortality is unknown (AMOC and IFT 2005: TC-18). Mexican wolf pups are difficult to distinguish from adults by early fall, therefore pup counts are conducted opportunistically after the denning period, but prior to October (AMOC and IFT 2005: TC-6). Documentation in the BRWRA of wild-born wolves breeding and raising pups has been made for six years in a row (2001-2007), and in 2007 approximately 90 percent of wolves in the Blue Range population were wild-born (AGFD et al. 2007).

During the first few months of life, gray wolf pups are gradually weaned from their parents, transitioning from nursing to feeding on semi-liquid regurgitated food provided by adult wolves at the den site, to consuming solid food. During this period, pups grow rapidly, likely due to high prey availability during summer months. Pup survival is typically highest in those areas of high prey availability (Fuller et al. 2003). Wolves are referred to as pups up to 1 year of age when they reach adult size and yearlings when 1-2 years of age (Packard 2003).

Juveniles begin hunting with adults when 4-10 months old (Packard 2003), remaining with their family until they disperse to establish a new territory. Wolves exploit their prey by hunting in packs. Adult wolves typically experience a feast or famine existence, gorging on freshly killed prey after successful hunts and subsequently able to survive for days with low food intake (Peterson and Ciucci 2003). Wolves buffer these extremes of food availability by burying food for later consumption (Peterson and Ciucci 2003). Food biomass intake rates of individual wolves vary significantly, from 0.5 to 24.8 kg/wolf/day, based on a variety of factors such as prey selection, availability and vulnerability of prey, and the effects of season or weather on hunting success (Mech and Peterson 2003, see Table 5.5). Minimum daily food requirements of an adult gray wolf have been estimated at 1.4 kg/wolf, or about 13 adult-sized deer per wolf per year, with the highest kill rate of deer reported as 6.8 kg/wolf/day (Mech and Peterson 2003). Prior to the Blue Range reintroduction, it was estimated that Mexican wolves would need to kill 1 mule deer every 12-13 days or one white-tailed deer every 8-9 days (Johnson et al. 1992). Wolves also scavenge on carcasses when available (Peterson and Ciucci 2003).

Wolf survival rates vary seasonally, as shifts in prey availability occur (Fuller et al. 2003). Annual survival rate of yearling and adult gray wolves is estimated at 0.55 to 0.86 (Fuller et al. 2003: Table 6.6). Documented causes of death include starvation, disease, human-caused mortality, and interactions with other wolves or predators (Fuller et al. 2003, Ballard et al. 2003). In the Blue Range population, causes of mortality have been largely human-related, including vehicle collision, illegal gunshot, lethal control, and capture complications, although dehydration, brain tumor, infection, snakebite, disease, mountain lion attack, and unknown causes have also been documented (AMOC and IFT 2005: TC-12). Between 1998 and 2007, illegal gunshot (28 of 62 deaths) and vehicle collision (12 of 62 deaths) were the 2 most prevalent causes of death (USFWS 2008: Population Statistics). In 2007, the annual survival rate was 0.53 (or a corresponding failure rate of 0.47, which includes both mortality and management removal of wolves) (AGFD et al. 2007).

Pack Formation and Movements

Wolves are social animals that live in hierarchical families, referred to as packs. Wolf packs consist of a breeding pair (formerly "alpha" (Packard 2003)) and their subordinate pup and yearling offspring (Mech 1970) although many variations of this typical pack structure have been observed (Mech and Boitani 2003). Pack size in the Blue Range population between 1998 and 2003 ranged from 2-11 (mean = 4.8) wolves (AMOC and IFT 2005: TC-12). Bednarz (1988) estimated historic Mexican wolf pack size as 2-8 animals.

To secure food, water, and shelter, a pack establishes an area, or territory, that is maintained by the breeding pair through scent-marking (Peters and Mech 1975), howling (Harrington and Mech 1983), and direct defense (Mech and Boitani 2003). Minimum territory size is the area in which sufficient prey exist to support the pack (Fuller et al. 2003), so territories vary in size depending on prey density or biomass and pack size. Average wolf pack territory size documented for 19 monitored packs in the Blue Range population between 1988 and 2003 averaged 462 km^2 +/- 63 km^2 (182 mi^2 +/- 24 mi^2) (AMOC and IFT 2005: TC-10). Bednarz (1988) predicted that reintroduced Mexican wolves would likely occupy territories ranging from 200-400 km^2 (approximately 125 to 250 mi^2), and hypothesized that Mexican wolf territories were historically comparable in size to those of small packs of northern gray wolves, but possibly larger, due to habitat patchiness (that is, mountainous terrain that included areas of unsuitable lowland habitat) and lower prey densities associated with the arid environment.

Wolf packs move within their respective territories as they forage and defend their territories (Mech and Boitani 2003). Wolves' daily movements vary in response to the distribution, abundance, and availability of prey. Seasonal movements vary as well: while rearing pups, adult wolves leave the den, returning throughout the day to care for their young. When pups are old enough to travel with adults, packs become nomadic, traveling throughout the territory, sometimes returning to rendezvous sites (Mech and Boitani 2003). Daily pack movements of less than 10 miles per day to over 40 miles in a 24-hour period have been documented in different wolf populations in different seasons (see Mech and Boitani 2003:32).

In addition to movements within territories, wolf travels typically include dispersal movements (Mech and Boitani 2003). An individual wolf, or rarely a group, will disperse from its natal pack in search of vacant habitat or a mate; dispersers are typically younger wolves of 9 to 36 months of age (Packard 2003). A yearling might make several dispersal forays before completely disassociating from the family (Messier 1985). These dispersals may be short to a neighboring territory, or may be long to find a mate and establish a territory. Dispersal of more than 1092 km (655 mi) has been documented in northern populations (Wabakken et al. 2007). Between 1998 and 2003, 45 wolf dispersals (natural dispersals and post-release movements) were documented in the Blue Range population, with an average distance of 87 km +/- 10 km (54 mi +/- 6 mi). This is likely an under-representation of true movement distances, due to management response required by the nonessential experimental-population designation when wolves disperse outside of the BRWRA. Wolves in the BRWRA primarily dispersed northwestward or southeastward, in the direction that mountain ranges lie within the area (AMOC and IFT 2005: TC-13).

Dispersing gray wolves usually travel alone and tend to have a high risk of mortality (Fuller et al. 2003). In the Blue Range population, 12 known mortalities were documented in association with dispersal between 1998-2003 (including natural dispersal and movements directly after release to the wild) (AMOC and IFT 2005: TC-14). Wolves that disperse and locate a mate and an unoccupied patch of suitable habitat usually establish a territory (Rothman and Mech 1979, Fritts and Mech 1981).

<u>Ecology and Habitat Description</u>

Wolves are top predators. They are generally not habitat specific and are considered to have fairly broad ecological capabilities (Wayne et al. 2004) and flexibility in using different prey and habitats (Mech 1991). Historically, wolves occupied every habitat in the northern hemisphere that supported populations of large ungulates (Mech 1991). The gray wolf hunts in packs, primarily pursuing medium to large hoofed mammals, potentially supplementing its diet with small mammals (Mech 1970). It is well documented that wolf density is directly related to the amount of ungulate biomass available and the vulnerability of ungulates to predation (see Fuller et al. 2003).

Wolves may play a variable role in ungulate population dynamics depending on the predator-prey interaction and the relative importance of other ecosystem factors (Messier 1994, Gasaway et al. 1993, Boutin 1992). Ungulates employ a variety of defenses against predation (e.g., aggression, migration), and wolves are frequently unsuccessful in their attempts to capture prey (Mech and Peterson 2003). Generally, wolves tend to kill less-fit prey (e.g., young, old, injured) that are predisposed to predation (Mech and Peterson 2003). Wolves may reduce prey numbers, especially during adverse conditions, but only in extreme circumstances have they been documented exterminating a prey population, and then only in a relatively small area (Mech and Peterson 2003).

Wolves may also impact ecosystem diversity beyond that of their immediate prey source in areas where their abundance is numerous enough to affect the distribution and abundance of other species (sometimes referred to as "ecologically effective densities" (Soule et al. 2003)) (Soule et al. 2005). This may occur through two mechanisms: 1) wolf predation may decrease the population of an herbivore that otherwise would competitively exclude other herbivores; and, 2) wolf predation on an herbivore may result in increases or decreases to lower tropic levels, cascading to the autotrophs at the bottom of the food web (i.e., "trophic cascade") (Terbough et al. 1999). Such effects have been attributed to gray wolf reintroduction in Yellowstone National Park (e.g., Ripple and Bescheta 2003, Ripple and Bescheta 2004).

Historically, Mexican wolves were associated with montane woodlands characterized by sparsely- to densely-forested mountainous terrain and adjacent grasslands in habitats found at elevations of 1219-1524 (4000-5000 ft) (Brown 1983). Wolves were known to occupy habitats ranging from foothills characterized by evergreen oaks (*Quercus* spp.) or pinyon (*Pinus edulus*) and juniper (*Juniperus* spp.) to higher elevation pine (*Pinus* spp.) and mixed conifer forests. Factors making these habitats attractive to Mexican wolves likely included an abundance of ungulate prey, availability of water, and the presence of hiding cover and suitable den sites. Early investigators reported that Mexican wolves probably avoided desert scrub and semidesert grasslands that provided little cover, food, or water (Brown 1983). Wolves traveled between suitable habitats using riparian corridors, and later, roads or trails (Brown 1983). Elevation in the BRWRA ranges from 1219-3353 m (4000-11000 ft), ranging from semi-desert grasslands to conifer forests, with ponderosa forests dominating the area in between (USFWS 1996).

Historically, Mexican wolves were believed to have preyed upon white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), collared peccaries (javelina) (*Tayassu tajacu*), pronghorn (*Antilocapra Americana*), bighorn sheep (*Ovis Canadensis*) jackrabbits (*Lepus spp.*), cottontails (*Sylvilagus spp.*), and small rodents

(Parsons and Nicholoupolos 1995); white-tailed deer and mule deer were believed to be the primary sources of prey (Brown 1983, Bednarz 1988, Bailey 1931, Leopold 1959).

Data from the Blue Range indicates that elk are the preferred prey (Brown and Parsons 2001, Reed et al. 2006), with wolves showing a preference for calf elk over adult elk (AMOC and IFT 2005: TC-14). Mexican wolves are also feeding on adult and fawn deer, unknown wild ungulates, cattle, small mammals, and occasionally birds (Reed et al. 2006). Scat analysis suggests that Mexican wolves in the Blue Range are concentrating on the largest prey available (elk), which is atypical given that wolves typically concentrate on the smallest or easiest prey available if two or more sources of prey are present. One hypothesis for this is that during the initial stages of the reintroduction, elk were naïve to predation by wolves and were the most numerous ungulate species; a second is that study methodology may have skewed data collection in order to minimize the probability of including coyote scat (Reed et al. 2006, Carrera et al. 2008).

The FEIS estimated that a population of 15,800 elk (average density 3.7/km^2), and 57,170 mule deer and white-tailed deer (average density 13.36/ km^2) were present in the BRWRA prior to the reintroduction of Mexican wolves (USFWS 1996). Although prey densities for the entire BRWRA are not available, wolf activity in the BRWRA appears to be located in areas of high elk density, as defined by state game management units (AMOC and IFT 2005: TC-14), and no evidence of food shortage has been observed (AMOC and IFT 2005: TC-21). The difference in historic versus current prey preference may in part be due to varying interpretations of Mexican wolf range; historic accounts which considered Mexican wolf range as southern Arizona and New Mexico into Mexico reflect the prevalence of deer (and relative absence of elk) in these areas, whereas elk are common, and sometimes more numerous than white-tailed or mule deer, in the current Mexican wolf range in the BRWRA (AMOC and IFT: TC-1).

Livestock are another widely available potential source of prey for Mexican wolves in the BRWRA. Historically, records of Mexican wolf exploitation of livestock were prominent (Young and Goldman 1944, McBride 1980, Brown 1983, Bednarz 1988); this is not surprising given that such reports were made by government and private wolf control agents whose jobs focused on depredating animals (and see Gipson and Ballard 1998, Gipson et al. 1998). When the reintroduction began, sheep and cattle grazing was permitted on approximately 69 percent of the BRWRA, with about half of the allotments being grazed year-round (USFWS 1996). Program projections predicted that at the reintroduction goal of at least 100 Mexican wolves, depredation levels of 1-34 cattle per year would occur (USFWS 1996). Between 1998 and 2007, 117 confirmed cattle depredations were documented (AMOC and IFT 2005: TC-15; USFWS 2006a, USFWS 2005; USFWS 2004; AGFD et al. 2007), or an average depredation rate of 25 cattle per 100 wolves per year. This depredation rate may represent an underestimate due to incomplete detection of wolf-killed cattle (Oakleaf et al. 2003). Between 1998 and 2007, 70 wolves were removed as a result of confirmed depredations (USFWS 2008: Reintroduction Project Statistics), or one wolf removal per 1.67 confirmed depredations.

Wolves and Non-prey

Wolves also interact with non-prey species. Although these interactions are generally not well documented, competition and coexistence may occur between wolves and other large, medium, or small carnivores (Ballard et al. 2003).

In the Southwest, wolves may interact with other wolves, coyotes, mountain lions (*Puma concolor*), and black bears (*Ursus americanus*) (AMOC and IFT 2005: TC-3). Aggression among wolves is typically associated with food shortages as wolves venture into neighboring territories to locate prey (Mech and Boitani 2003). Observation of wolf and coyote interactions in other regions have documented decreased coyote density in areas of high wolf density and that wolves occasionally kill or eliminate coyotes (Ballard et al. 2003). Bednarz (1988) suggested that prior to wolf extirpation, Mexican wolves excluded coyotes from many areas. A current study of Mexican wolf and coyote diets in the BRWRA shows that wolves and coyotes have similar diets consisting mainly of elk (Carrera et al. 2008). It is not known whether coyotes are scavenging elk carcasses from wolf kills or preying on elk directly, although both behaviors have been documented in other areas. It is hypothesized that this shared source of prey may cause competition between wolves and coyotes that will result in wolves killing coyotes (Carrera et al. 2008).

Bednarz (1988) also hypothesized that wolves and mountain lions interacted historically, given their overlapping habitats and shared prey source of mule deer, but suggested that wolves may have exploited gentler sloping terrain, with mountain lions hunting in steeper craggy mountainous terrain. The potential for competition between wolves and lions certainly exists in areas where spatial overlap is extensive and prey selection patterns are similar (see Kunkel et al. 1999), although differences in hunting behavior and prey vulnerability to wolves and mountain lions have been observed (see Husseman et al. 2003). One Mexican wolf death from a mountain lion attack has been recorded in the BRWRA (AMOC and IFT 2005: TC-12). Gray wolves have been known to kill black bears near their dens and to take over kill sites occupied by black bears (Ballard and Gipson 2000, Ballard et al. 2003), but interactions between Mexican wolves and black bears have not been documented. Two other Mexican wolf deaths have been attributed to predators, but identification of specific predators were not provided (USFWS 2008: Population Statistics, USFWS 2004, USFWS 2006a).

Wolf – Human Interactions

Wolves' reactions to humans include a range of non-aggressive to aggressive behaviors, and may depend on their prior experience with people. For example, wolves that have been fed by humans, habituated, or reared in captivity may be more apt to show fearless behavior towards humans than wild wolves; diseased wolves may also demonstrate fearless behavior (McNay 2002, Fritts et al. 2003). In North America, wolf-human interactions have increased in the last three decades, likely due to increasing wolf populations and increasing visitor use of parks and other remote areas (Fritts et al. 2003). Generally, wild, unhabituated wolves are not considered a threat to human safety (McNay 2002). However, one recent human death in Canada has been attributed to wolves (International Wolf Center 2008).

In the BRWRA, wolf-human interactions have been documented. For example, between 1998 and 2003, 33 cases of wolf-human interaction were documented in the BRWRA; the majority of these (64 percent) were considered investigative searches in which wolves ignored human presence. In several cases (27 percent), wolves approached humans in a non-threatening manner, and in three reports wolves displayed aggressive behavior (charging) toward humans (AMOC and IFT 2005: TC-15). A majority of the interactions involved wolves recently released from captivity, suggesting that wolves released from captivity may be more prone to initial fearless behavior toward humans, despite appropriate captive management and selection criteria for release candidates (AMOC and IFT 2005: TC-22). Wolves are known to kill dogs virtually everywhere the two coexist (Fritts et al. 2003), thus the presence of dogs may provoke investigative or aggressive behavior. Dogs were present in many of the cases (including the three charges, in which the aggression appeared to focus on the dogs rather than the humans) (AMOC and IFT 2005: 22). Aversive conditioning or removal of the wolf was applied in all cases of wolf-human interaction.

Humans may also be a significant source of mortality for wolves. Human-caused mortality is a function of human densities in and near occupied wolf habitat and human attitudes toward wolves (Kellert 1985, Fritts and Carbyn 1995, Mladenoff et al. 1995). Sources of mortality may include accidental incidents such as vehicle collision, or intentional incidents such as illegal shooting of protected wolves. In areas where humans are tolerant to the presence of wolves, wolves demonstrate an ability to persist in the presence of a wide range of human activities (e.g., near cities and congested areas) (Fritts et al. 2003). In the BRWRA, vehicular collision and illegal shooting are the two biggest mortality sources of Mexican wolves (USFWS 2008: Population Statistics) (and see “Physical Description and Life History”, above).

CONSERVATION ASSESSMENT

Threats to the Gray Wolf in the Southwest

The ESA defines an "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range" 16 U.S.C 1532(6). Similarly, a "threatened species" is "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" 16 U.S.C 1532(20). Species are listed as threatened or endangered if it is determined that one or more of the following five factors in section 4(a)(1) of the ESA are responsible for their condition:

(A) The present or threatened destruction, modification, or curtailment of its habitat or range;
(B) Overutilization for commercial, recreational, scientific, or educational purposes;
(C) Disease or predation;
(D) The inadequacy of existing regulatory mechanisms; or,
(E) Other natural or manmade factors affecting its continued existence.

Subsequent 5-factor analyses are conducted periodically while a species is listed to assess its status and ensure that conservation actions are addressing current threats. Finally, a 5-factor analysis is conducted when a species is proposed for delisting due to recovery to ensure that none of the factors continue to threaten or endanger the species.

Several 5-factor analyses have been conducted for the Mexican wolf. In the initial proposal to list the Mexican wolf as endangered in 1975, the Service found that threats from habitat loss (Factor A), sport hunting (Factor B), and inadequate regulatory protection from human persecution (Factor D) were responsible for the subspecies' decline and near extinction (40 FR 17590-17591, April 21, 1975). In the 1978 listing of the entire gray wolf species as endangered throughout the coterminous United States and Mexico (except for Minnesota where it was classified as threatened), the Service identified the same threats (43 FR 9607-9615, March 9, 1978).

In 2003, when the Service reclassified the gray wolf into three distinct population segments, the agency assessed threats to the Mexican wolf as a part of the SWDPS (68 FR 15804-15875, April 1, 2003). The reclassification rule stated that habitat destruction or modification (Factor A) was not currently considered a threat or deterrent for restoration of southwestern (Mexican) gray wolves based on the 1982 Mexican Wolf Recovery Plan which stated that sufficient habitat existed at that time to support current recovery plan objectives. "Take" for commercial or recreational purposes (Factor B) was not considered a threat. 16 U.S.C 1532(19). Diseases and parasites (Factor C), which are known to be an important consideration in wolf conservation, were not known to be significant factors in the decline of the Mexican wolf, and there was no reason to believe they would hinder recovery. Illegal killing ("human predation", considered Factor C in the rule) was recognized as a factor that may slow, but not likely preclude, recovery in the Southwest. Regulatory protection of reintroduced Mexican wolves was deemed adequate (Factor D). Finally, public attitudes toward gray wolves were cited as a primary determinant in the long-term recovery status of wolves (Factor E), and the rule anticipated that the potential for human-wolf conflicts would increase as the number of wolves increased.

A current 5-factor analysis provides an opportunity to assess threats to the Blue Range population based on information available since the 2003 reclassification.

Factor A

Factor A considers whether habitat alteration threatens the species in either the present or the future (i.e., "present or threatened destruction, modification, or curtailment of its habitat or range"). While knowledge of current and ongoing habitat alteration informs an assessment of threats to the present Blue Range population, the degree to which habitat alteration may hinder future recovery would be made by considering projections of future events and landscape trends in relation to recovery criteria that specify the abundance or distribution of wolves needed for recovery and by considering any future modifications to the boundaries of the BRWRA/MWEPA. Lack of an up-to-date recovery plan containing such criteria and lack of a determination of how the BRWRA/MWEPA may be modified preclude such an analysis (see Road to Recovery and Status of National Gray Wolf Recovery and Implications for the Mexican Wolf, above). However, available results from simulations of future wolf habitat will be briefly discussed for insight into development trends that may warrant attention as decisions affecting the future of the reintroduction and recovery effort are made.

The three fundamental ecological conditions necessary for wolf habitat include large area size, adequate prey, and security from human exploitation (Carbyn and Fritts 1995, and see "Gray Wolf Biology and Ecology", above). Factor A considers roads as an element of habitat suitability, specifically as they relate to wolf mortalities due to vehicle collision (e.g., a form of human exploitation). Other sources of human-caused mortality will be discussed under Factors D and E, below.

The BRWRA was selected for the reintroduction effort based on its size and its abundance of native prey species, as well as its topography, water availability, Federal land status, human density, road density, and historic inhabitance by wolves (USFWS 1996: 2-2 - 2-4). Since the designation of the BRWRA in 1998, the recovery area has not been curtailed in size, and thus continues to provide 17,775 km^2 (6,845 mi^2) of ecologically suitable wolf habitat, 95% of which occurs on Forest Service lands (63 FR: 1752-1772). The 1982 Mexican Wolf Recovery Plan suggested that a population of 100 wolves could likely be supported in an area of 5000 mi^2 (USFWS1982), and the FEIS found that the BRWRA was large enough to support the recovery's plan recommendation to establish a population of at least 100 wolves (USFWS 1996: 2-5). In 2000, WMAT agreed to allow wolves to inhabit FAIR, and in 2002 signed an agreement allowing direct release of wolves onto FAIR, providing an additional 6,475 km^2 (2,500 mi^2) of wolf habitat. Thus, since the reintroduction project began, the size of the reintroduction area has effectively increased.

Initial projections in the FEIS estimated that the BRWRA contained adequate prey to support a population of 100 wolves; prior to the reintroduction, a population of 15,800 elk (average density 3.7/km^2), and 57,170 mule deer and white-tailed deer (average density 13.36/ km^2)

were estimated to be present in the BRWRA (USFWS 1996). The 3-Year Review hypothesized that based on the author's estimation of prey base, the BRWRA could support a minimum of over 200 wolves (Paquet et al. 2001). In the 5-Year Review, AMOC recognized that although AGFD, NMDGF, and WMAT collect data on prey abundance, data are not available or comparable for the entire BRWRA. However, AMOC concluded that adequate prey exists based on lack of indication that wolves are food limited. That is, starvation and interspecific strife have not been documented in the Blue Range population, and only two cases of significant weight loss have been documented (AMOC and IFT: TC-21). However, the 5-Year Review also hypothesized that inadequate prey vulnerability (as opposed to biomass) due to ephemeral snow pack in winter months may contribute to small litter sizes (AMOC and IFT: TC-18), although conclusive data has not been gathered to support or negate this hypothesis and other hypotheses for litter size are offered. The 5-Year review also stated that no detectable changes in big game availability have occurred as a result of wolf reintroduction (AMOC and IFT: TC- 21). In recognition of their need for information related to prey abundance and distribution, AMOC recommended that an advisory group be convened to provide technical expertise on native ungulate populations, prey base dynamics, and relevant monitoring techniques (AMOC and IFT 2005: ARC – 6). There is no indication from annual project reports conducted since the 5-Year Review that prey availability is a limiting factor for the Blue Range wolf population USFWS 2006a; AGFD et al. 2007). Based on this information, it seems likely that the BRWRA contains adequate prey to support the reintroduced population, but adequate information is unavailable to provide a firm conclusion.

Roads are a significant form of habitat modification to wolves because they are known to facilitate human access to areas occupied by wolves. Specifically, roads are a source of vehicular traffic and wolf mortality due to vehicle collision, as well as providing numerous access points for hunters and trappers, and supporting more residences, farms, and domestic animals, which increase the likelihood of wolf interactions with humans and livestock. Thus, it has been recommended that areas targeted for wolf recovery have low road density of approximately 1 mile of road per square mile of area, or 1.6 km of road per 2.56 square kilometer (Thiel 1985). Road density in the BRWRA was estimated at 0.8mi road/mi^2 area prior to the reintroduction (Johnson et al. 1992: 48). Roads in the BRWRA primarily exist to support forest management, livestock grazing, recreational access, and transport of forest products (USFWS 1996: 3-13). In the decade since the reintroduction has been underway, calculation of road density in the Gila and Apache National Forests has not been conducted, and a formal comparison between prior and current road density in the BRWRA is not possible without that information.

Vehicular collision has been the second biggest source of mortality for wolves in the Blue Range population between 1998 and July 2008 (12 out of 62 total documented Mexican wolf deaths) (USFWS 2008: Population Statistics). With the exception of a high of four vehicular-related wolf deaths in 2003, annual vehicular-related deaths have ranged from zero to two per year (USFWS 2008: Population Statistics). The loss of any animal, particularly a breeding adult, tends to be more important when a population is small in size and has a limited number of breeding adults. However, although this cause of death is notable in that it ranks as the second leading cause of mortality in the Blue Range population, it does not seem to be occurring at a level significant to hinder population growth toward the population objective of 100 and has not been identified in previous project evaluations (e.g., Paquet et al. 2001, AMOC and IFT 2005) as a significant threat. In lieu of information on changes in road density (or traffic patterns, for which a baseline was not provided in the FEIS) in the BRWRA and in areas outside of the BRWRA through which wolves may try to disperse, the annual number of mortalities from vehicle collision is relied upon as an indication of the severity of this threat, which seems to be minimal at current levels.

Habitat necessary for wolves in the future will entail the same ecological conditions as it does today, namely adequate prey, large areas, and security from excessive mortality (Fritts and Carbyn 1995). Several regional spatially-explicit population habitat viability analyses have been conducted in recent years to identify suitable gray wolf habitat in the Southwest, southern Rockies, and Mexico, and assess how suitability may change over time. Given that site-specific assessment of future habitat threats is precluded by lack of recovery criteria and potential modification to the BRWRA/MWEPA (see "The Road to Recovery", above) consideration of these analyses can at least provide an indication of trends that may affect recovery and should be monitored.

According to Carroll et al. (2003, 2005, 2006), there are a number of adequately-sized, ecologically suitable blocks of habitat in the Southwest, southern Rockies, and Mexico for establishment of wolf populations. However, model simulations suggest that these sites are impacted in the future by human population growth and associated road development on public and private lands surrounding core wolf habitat (Carroll et al. 2003, Carroll et al. 2005, Carroll et al. 2006).

For example, simulations of gray wolf establishment at sites in the Southwest (Utah, Colorado, Arizona, New Mexico, and Trans-Pecos Texas) and Mexico (Sonora, Chihuahua, Coahuila, Nuevo Leon, Durango, Tamaulipas, and portions of Zacatecas and San Luis Potosí) suggest that habitat that is currently suitable for reintroduction and persistence of gray wolf populations will be less able to support wolf populations in the year 2025 (Carroll et al. 2005). Development (i.e., roads) on public and private land resulted in a 25 percent decline in carrying capacity of the United States portion of the region by the year 2025, with private land development accounting for two-thirds of this decline. Extinction risk at individual reintroduction sites for current scenarios was generally low, but increased in future scenarios by as much as 20 percent. The increase in extinction risk was in part based on a metric used to estimate wolf mortality that captures the association between wolf mortality and proximity to roads and areas of high human density. (This metric captures a suite of human-caused mortality sources related to roads, e.g., vehicle collisions as well as poaching, therefore it is impossible to tease out effects solely from vehicle collision and simulation results are perhaps equally applicable to considerations of social tolerance and illegal killing, Factor E). Simulations of New Mexico and Colorado reintroduction sites showed the greatest vulnerability to landscape development, as compared to larger core habitat blocks in Arizona. Connectivity between reintroduction sites also diminished substantially by 2025, leaving some sites relatively isolated (Carroll et al. 2005).

In addition to the trends of increasing human population growth and resultant development on public and private lands explored in these analyses, other potentially significant sources of habitat modification that may impact future recovery efforts in the region could include the United States-Mexico border fence or climatic factors, depending on the location of future reintroduction and recovery efforts.

Summary statement: Threats related to habitat destruction, modification, or curtailment do not likely threaten the Blue Range Population at the current time, based on an increase in the area available to reintroduced wolves since the project began, lack of indication that wolves are food-limited, and a relatively small number of vehicular-related wolf deaths each year. Continued attention to habitat-related threats, particularly those that affect area size, prey availability, and road-related mortality, will be necessary as the BRWRA population expands toward the population objective of 100, if modification to the BRWRA/MWEPA occurs, and when recovery criteria are developed.

In spite of this finding, there are several issues closely related to habitat curtailment that warrant mention: the regulations associated with the internal and external boundaries of the BRWRA, and management procedures related to livestock depredation in the BRWRA. These issues are discussed under Factor D, below, because they are viewed as management constraints placed on habitat that otherwise is of sufficient size and ecological condition to support the existing population.

Factor B

Since the inception of the Mexican wolf reintroduction, the Service has not authorized legal killing or removal of wolves from the wild for commercial, recreational (i.e., hunting), scientific, or educational purposes. Illegal killing of wolves for their pelts is not known to occur in the Southwest, nor is illegal trafficking in wolf pelts or parts known to occur. Mexican wolf pelts and parts from wolves that die in captivity or in the wild are used for educational purposes, such as taxidermy mounts for display, when permission is granted from the Service; most wolf parts are sent to a curatorial facility at the University of New Mexico to be preserved, catalogued, and stored. A recreational season for wolf hunting is not currently authorized in the Southwest, and would only become so in conjunction with post-delisting monitoring and applicable state regulations. Several ongoing Mexican wolf research projects occur in the BRWRA or adjacent tribal lands by independent researchers or project personnel, but these studies have utilized radio-telemetry, scat analysis, and other non-invasive methods that do not entail direct handling of, or impact to, wolves. Non-lethal research for the purpose of conservation is also conducted on Mexican wolves in the SSP captive breeding program; current projects include research on reproduction, artificial insemination, and semen collection (USFWS 2006a).

Interagency Field Team and other agency personnel handle and confine wolves during the administration of vaccines and medical treatment, and during non-lethal control or capture actions in the field and captive pre-release facilities, but these activities are not considered scientific in purpose; rather they are regular management activities necessary for implementation of the reintroduction project. These activities have rarely resulted in the unintended death of a wolf (two capture-related wolf deaths in the wild (USFWS 2006a, USFWS 2001) and one capture-related wolf death in a captive pre-release facility (Siminski 2005).

Summary statement: Overutilization for commercial, recreational, scientific, or educational purposes is not considered a threat to the Mexican wolf because the Service does not authorize legal killing or removal of wolves from the wild for commercial, recreational (i.e., hunting), scientific, or educational purposes, illegal killing or trafficking for pelts is not know to occur, and non-lethal techniques are used during Mexican wolf research.

Factor C

A number of viral, fungal, and bacterial diseases and endo- and ectoparasites have been documented in gray wolf populations (Kreeger 2003). Typically, diseases are transmitted through direct contact (e.g., feces, urine, or saliva) with an infected animal, or by aerosol routes. Parasites are picked up through water, food sources, or direct contact; wolves are able to tolerate a number of parasites, such as tapeworms or ticks, but at times such organisms are lethal (Kreeger 2003).

There is little research specific to disease or contaminant issues in Mexican wolves, and little documentation of disease prevalence in wild wolves in the Blue Range population. Information from studies of other wild North American gray wolf populations is summarized in the threat analyses conducted for the delisting of the Great Lakes and Northern Rockies populations based on disease occurrences in those geographic regions, and can be referenced for a broader list of diseases than those described below (see 72 FR 6051-6103, February 8, 2007 and 73 FR 10513-10560, February 27, 2008). Contaminants that occur in the environment may have the potential to affect wolves through transfer in the food chain, but little data has been published on pollutant or pesticide levels in wolves (e.g., see Shore et al. 2001).

Mexican wolves are routinely vaccinated for rabies, distemper, parvovirus, and corona virus before release to the BRWRA from captive facilities USFWS 2006a). Wolves that are captured in the wild are vaccinated for the same suite of diseases. The following descriptions of these diseases have been summarized based on Kreeger 2003 unless otherwise noted.

Rabies, caused by a rhabdovirus, is an infectious disease of the central nervous system typically transmitted by the bite of an infectious animal. Fox variants of rabies have been the primary vectors when the disease is reported in wolves. An animal infected by rabies may exhibit a variety of symptoms as it proceeds through several stages of infection; the animal may experience paralysis of the throat and excessive salivation, advancing to a state of agitation in which the animal may bite at inanimate objects, people, or other animals, to an advanced paralysis that leads to death. Rabies can spread between infected wolves in a population (e.g., among and between packs), or between populations, resulting in severe population declines. Once an animal is infected, it is untreatable.

A rabies outbreak in and near the BRWRA began in 2006 in eastern Arizona and continues through 2008, with positive rabies diagnoses (fox variant) in both foxes and bobcats. No wolves in the Blue Range population have been diagnosed with rabies during this outbreak (AZDHS 2008: Rabies Statistics and Maps) or throughout the history of the reintroduction (USFWS 2008: Population Statistics).

Canine distemper, caused by a paramyxovirus, is a febrile disease typically transmitted by aerosol routes or direct contact with urine, feces, and nasal exudates. Symptoms of distemper may include fever, loss of appetite, loss of coordination (ataxia), shortness of breath (dyspnea), swollen feet, and eye and nose discharge. Death from distemper is usually caused by neurological complications (e.g., paralysis, seizures). Once an animal is infected, distemper is untreatable. Although wolf populations are known to be exposed to the virus in the wild, mortality from distemper in wild wolves is uncommon.

Two Mexican wolf pups brought to a wolf management facility in 2000 from the wild were diagnosed with distemper, indicating they were exposed to the disease in the wild, and died in captivity (AMOC and IFT: TC-12). These are the only known mortalities due to distemper documented in relation to the Blue Range population, and are considered captive deaths rather than wild mortalities (USFWS 2008: Population Statistics).

Canine parvovirus is an infectious disease caused by a virus that results in severe gastrointestinal and myocardial (heart disease) symptoms. Canine parvovirus can be transmitted between canids (e.g., wolves, coyotes, dogs), but not to other hosts such as humans or cats (although there are other strains of parvovirus that can infect both). Canine parvovirus is typically transmitted through contact with feces or vomit, where it can survive for months. Symptoms of an infected adult animal may include severe vomiting and diarrhea, resulting in death due to dehydration or electrolyte imbalance. Pups may die from myocardial (heart) disease if infected with canine parvovirus while in utero or soon after birth from cardiac arrhythmias. Although canine parvovirus has been documented in wild wolf populations, there are few documented mortalities due to parvovirus; it is hypothesized that parvovirus is a survivable disease, although less so in pups. Captive wolves have been successfully treated with fluid therapy until symptoms abated.

Three Mexican wolf pups brought to wolf management facilities from the wild died from canine parvovirus in 1999, indicating that they had been exposed to the disease in the wild (AMOC and IFT 2005: TC-12). Mortality from canine parvovirus has otherwise not been documented in the Blue Range population (USFWS 2008: Population Statistics). (Note: one pup died in the pen in the wild and is the one disease-related mortality documented for the wild population, the other two pups died at a pre-release captive facility and are considered captive mortalities.)

Corona virus is an infectious disease transmitted primarily through feces (Zarnke et. al. 2001). Symptoms in canids (dogs, wolves, coyotes) include diarrhea and dehydration. Infection of dogs and coyotes by both corona virus and canine parvovirus has been documented, resulting in symptoms similar to canine parvovirus but more severe (Zarnke et al. 2001). Mortality due to corona virus has not been documented in the Blue Range population (USFWS 2008: Population Statistics).

Monitoring of collared wolves in the Blue Range population has not documented significant levels of wolf mortality due to disease. Neither the 5-Year Review nor annual reports in the following years indicate that disease is a concern or is significantly impacting population growth rate. Of 62 total documented wolf deaths between 1998 and July 2008, one death was attributed to disease (canine parvovirus) (USFWS 2008: Population Statistics). Some diseases are more likely to spread as wolf-to-wolf contact increases (Kreeger 2003), thus the potential for disease outbreaks may increase as the population expands in numbers or density. Even if disease occurrences increase in number, disease may not threaten the population when considered as an isolated threat; however, as with any mortality source, its significance may increase when considered in conjunction with other demographic factors, such as low recruitment.

Summary statement: Disease is not considered a threat to the Mexican wolf based on known occurrences in the Blue Range population and the active vaccination program.

In addition to disease, Factor C also requires consideration of threats due to predation. No wild predator regularly preys on wolves (Ballard et al. 2003). Although large prey may occasionally kill wolves during self-defense (Mech and Peterson 2003), this is rare and not considered predation on the wolf. Between 1998 and 2007, three documented Mexican wolf mortalities were due to predators (USFWS 2006a, AGFD et al. 2007). Monitoring of Northern Rockies wolf populations demonstrated that wolf-to-wolf conflicts may be the biggest source of predation among gray wolves, but this typically occurs from territorial conflicts and has not occurred at a level sufficient to affect these populations' viability (73 FR 10513-10560, February 27, 2008). As the Mexican wolf population begins to saturate available habitat, wolf mortalities resulting from territorial conflicts may become more prevalent. However, information does not indicate that wolf-to-wolf or other sources of predation are a threat to the current or future Mexican wolf recovery effort.

Intentional human-caused mortality of wolves has sometimes been considered "human predation" by the Service and assessed under Factor C, but this assessment places intentional human-caused mortality under Factor E, as it is an indication of social tolerance of wolves.

Summary statement: Predation is not considered a threat to the Mexican wolf because no wild predator regularly preys on wolves and only a small number of predator-related wolf mortalities have been documented in the Blue Range population.

Factor D

A number of concerns have been raised regarding the adequacy of regulatory mechanisms being applied to the Mexican wolf recovery program and reintroduction project pursuant to the ESA. To some degree, it is normal to expect that significant concerns will be raised by different factions of society during the implementation of a complex program such as wolf recovery. The fact that such concerns exist does not necessarily mean that regulatory mechanisms are inadequate for the conservation and recovery of the species. Rather, it may indicate that there are several methods for achieving objectives, with pros and cons inherent in each. For example, some who support wolf recovery may want wolves to have endangered status across their entire range, whereas others may support the flexibility offered by a non-essential experimental designation in certain locations. However, when both the public and the implementing agencies indicate that regulatory mechanisms are not fully supporting stated objectives (i.e., establishment of a wild population of at least 100 wolves), a mid-course correction in strategy may be necessary.

The adequacy, or appropriate implementation of the following regulatory mechanisms have been raised in the 3-Year Review, 5-Year Review, annual reports of the reintroduction project, or active litigation: 1) the internal and external boundaries of the BRWRA, including the configuration of the Primary and Secondary Recovery Zones and the regulations governing removal of wolves due to boundary violations; 2) regulations or management procedures for livestock management (e.g., carcass removal); 3) management procedures related to livestock depredation (SOP 13); 4) implementation of conservation actions by Federal agencies pursuant to section 7(a)(1) of the ESA; 5) the transfer of management authority of the reintroduction project from Service to AMOC; and, 6) revision of the 1982 Mexican Wolf Recovery Plan.

The efficacy of the configuration of the internal and external boundaries of the BRWRA has been questioned in both the 3-Year and 5-Year reviews, as well as internally within the agencies responsible for the reintroduction and recovery effort. Paquet et al. (2001:61) stated that the small size of the Primary Recovery Zone (the Apache National Forest, the zone designated for release of wolves) was hindering rapid establishment of the wild population and recommended that the Final Rule be modified to allow releases in the Secondary Recovery Zone (the Gila National Forest). In a follow-up to this recommendation, AMOC provided a detailed explanation in the 5-Year Review of why modification of the internal boundaries of the BRWRA had not yet occurred by 2005. In short, initial progress toward revising the Final Rule between 2001 and 2003 was eclipsed by the Service's subsequent intent to revise the 1982 Mexican Wolf Recovery Plan to provide big picture guidance for the recovery program before proceeding with revision to the reintroduction project. After the SWDPS recovery team was put on hold due to litigation in 2005, the Service indicated that AMOC should resume consideration of necessary modifications to the reintroduction project, including boundary modifications (AMOC and IFT 2005: AC-14-17). AMOC concluded in the 5-Year Review that the provision governing release of wolves solely into the Primary Recovery Zone restricts the pool of available release candidates, restricts release of wolves for management purposes such as genetic augmentation, and causes public perception issues between the states of Arizona and New Mexico (AMOC and IFT 2005: AC-14-15). Thus, the 5-Year Review recommended that the Final Rule be modified to expand the area in which wolves could be released and translocated.

In the 3-Year Review, Paquet et al. (2003: 23, 65) also noted that wolves were dispersing outside of the external boundaries of the BRWRA into the MWEPA and would continue to do so, given the long-distance movements of normal wolf activity. They concluded that the provision in the Final Rule requiring removal of wolves that establish territories wholly outside of the BRWRA boundaries was contrary to normal wolf movement patterns and recommended that the Final Rule be modified to allow wolves to establish territories outside of the BRWRA. In the 5-Year Review, AMOC again explained why action had not been taken toward this recommendation by 2005, referencing the previous explanation of progress toward revising the internal boundaries, as well as acknowledgement that the requirement for removal of wolves due to boundary violations had been carefully developed during the planning of the reintroduction based on public comment (AMOC and IFT 2005: AC-17-19). AMOC concluded, based on several additional years of project implementation since the 3-Year Review, that boundary removals were hindering natural dispersal and colonization, creating unrealistic public expectations that wolves could be successfully captured when they left the BRWRA, and creating staffing and logistical concerns related to the effort required to attempt such removals (AMOC and IFT: AC-18). Calculations in the 5-Year Review demonstrated that a hypothetical wolf dispersing the average lone-movement distance (i.e., 87 km) in a random direction from the center of the BRWRA and FAIR would end up outside the BRWRA 66 percent of the time, and indeed project data was showing that the majority of single dispersers were ending up outside of the BRWRA (AMOC and IFT: TC-20). Between 1998 and December 2007, removal of wolves from the wild for boundary violations was the second leading cause of management removal in the BRWRA (39 boundary removals out of 142 total removals) (USFWS 2008: Population Statistics). Thus, AMOC recommended that the Final Rule be modified to allow wolves to expand into the MWEPA in order to reduce removals associated with boundary violations (AMOC and IFT: TC-24) and committed to further analysis of the extent to which boundaries should be modified (AMOC and IFT: ARC-3).

During the planning of the reintroduction project, the amount of permitted public lands grazing in the BRWRA was identified as a likely source of conflict for the reintroduction due to the potential for wolf depredation of livestock and related social and economic issues (USFWS 1996: 2-4). In the 3-Year Review, Paquet et al. (2001: 52-54) concluded that livestock depredation by wolves was occurring and that wolf-livestock interaction would continue due to the spatial and temporal occurrence of livestock in the recovery area. They stated that sufficient information was not provided for a detailed analysis of the adequacy of the depredation control program. They followed this with a recommendation that implementation of specific livestock husbandry techniques, particularly removal of carcasses, could lessen the potential of wolves becoming habituated and subsequently depredating livestock and therefore should be required for livestock operators on public lands (p. 67).

In the 5-Year Review, AMOC analyzed available data to determine the extent to which a carcass feeding issue exists. They concluded that the number of depredations committed after wolves were known to have fed on a carcass was too small of a sample size to determine whether a "depredation predisposition" exists (AMOC and IFT: AC-31). They also investigated Federal and State authority to regulate carcass removal and related husbandry practices and determined that Federal agencies (Forest Service and Bureau of Land Management) do not have the authority to require lease and permit holders to remove carcasses from public land, and that State statutes further constrain carcass removal (AMOC and IFT 2005: AC-30 – 31). Thus, AMOC committed to development of a conceptual incentives program that would address this and related wolf nuisance and depredation issues (AMOC and IFT 2005: AC-32). Two recent studies of factors affecting wolf depredation of cattle in the Northern Rockies and the Great Lakes provide inconclusive results as to whether wolves display a depredation predisposition (Mech et al. 2000, Bradley and Pletscher 2005).

A second facet of conflict that has arisen between wolves and livestock in the BRWRA relates to management response to depredation events. Adaptive Management Oversight Committee developed Standard SOP 13 in 2005 to specify criteria for determining the status of depredating and non-depredating wolves and provide guidelines for conducting control actions in response to depredation events (USFWS 2008: Blue Range Reintroduction Project – Standard Operating Procedures). In particular, SOP 13 requires the removal of wolves involved in three depredation incidents in a 365-day period. Between 1998 and December 2007, wolf-livestock conflict was the leading cause of management removal of wolves in the Blue Range population (70 livestock-related wolf removals out of 142 total removals); removals in 2006 and 2007, the years in which SOP 13 was actively implemented, had the highest number of removals of all years (16 and 19 removals, respectively) (USFWS 2008: Population Statistics). At the end of 2007, the lead agencies acknowledged that the aggressive removal rate of wolves by management due to depredation, nuisance, and boundary issues was hindering population growth, although they also reiterated the importance of demonstrating a high level of responsiveness to conflicts (AGFD et al. 2007). Two lawsuits currently challenge the Service's adoption of SOP 13 for failure to comply with NEPA (Defenders of Wildlife et al. v. Tuggle et al., Civil No. 4:08-cv-280-DCB (D. Ariz.)) and on the grounds that SOP13 does not "further the conservation of" the Mexican wolf as required by section 10(j) of the ESA and is therefore arbitrary and capricious under the Administrative Procedures Act (APA) (WildEarth Guardians et al. v. USFWS et al., Civil No. 2:08-cv-820-DCB (D. Ariz.)). These challenges have not yet been resolved, but resolution of the second case in particular will provide insight into whether SOP 13 contributes to the adequacy of existing regulatory mechanisms for the Mexican wolf.

These two lawsuits also challenge the adequacy of regulatory mechanisms for the Mexican wolf on two other counts. The WildEarth Guardians et al. v. USFWS et al. lawsuit alleges the failure of the Forest Service to develop and carry out a program for the conservation of the Mexican wolf pursuant to section 7(a)(1) of the ESA, while the Defenders of Wildlife et al. v. Tuggle et al. lawsuit alleges the Service has delegated authority to AMOC for the reintroduction project (see Road to Recovery, above) in violation of both the ESA and the APA. Resolution of these challenges will likewise provide insight into whether these regulatory provisions are contributing to the conservation and recovery of the Mexican wolf.

Last, both the 3-Year and 5-Year reviews reiterate that the 1982 Mexican Wolf Recovery Plan fails to provide current guidance to the reintroduction, particularly regarding establishment of objective and measurable recovery criteria, and recommend that a revised plan be developed (Paquet et al. 2001:64, AMOC and IFT 2005: AC-13). A revised recovery plan has still not been finalized, for complex logical reasons (see Status and Implications of National Gray Wolf Recovery for the Mexican Wolf, above, as well as AMOC and IFT 2005: AC-10).

While a number of substantial concerns have been raised related to the adequacy of the ESA's regulatory mechanisms for the Mexican wolf reintroduction project and gray wolf recovery program in the Southwest, the concerns (including those being resolved through litigation) are aimed at the interpretation and implementation of available mechanisms by the Service and its interagency partners rather than the adequacy of the mechanisms themselves.

Reintroduction and recovery programs can be, by their very nature, management-intensive and subject to trial and error. While the conservation assessment reiterates prior findings that several of the ESA's provisions have not been implemented in a manner or to the degree that information now suggests is necessary, the assessment acknowledges the ongoing efforts of the Service and the lead agencies to address these inadequacies. Specifically, these efforts include the quarterly meetings of the Adaptive Management Working Group, which includes AMOC and other State and county governments, to gather input and address issues of concern (AGFD 2008); the intent of the Service to modify the Final Rule as demonstrated by a recent public scoping process, including a series of public meetings held in November and December 2007 to consider modifications to the Final Rule (72 FR 44065-44069, August 7, 2007; and see USFWS 2008: Rule Modification); multiple attempted revisions of the 1982 Mexican Wolf Recovery Plan; and the development of a Mexican-wolf-specific incentives program and application of existing incentives available through State programs to address socioeconomic issues related to wolf conflicts.

Summary statement: Current interpretation and implementation of several regulatory mechanisms are not adequately supporting the reintroduction and recovery effort. Modifications to the implementation of these mechanisms that will support the reintroduction and recovery effort have been identified and are actively being pursued.

Factor E

Public opinion has long been recognized as a significant factor in the success of gray wolf recovery efforts (considerable literature exists on this topic, e.g., see Fritts et al. 2003, Boitani 2003, Primm and Clark 1996, Rodriquez et al. 2003, Bangs et al. 2004) and illegal killing of wolves by those opposed to wolf reintroduction and recovery efforts is proof of its importance.

In the Southwest, extremes of public opinion vary between those who strongly support or object to the recovery effort. Support stems from such feelings as an appreciation of the wolf as an important part of nature and an interest in endangered species restoration, while opposition may stem from negative social or economic consequences of wolf reintroduction, general fear and dislike of wolves, or Federal land-use conflicts (Unsworth et al. 2005, Duda and Young 1995, Research and Polling 2008). Some ranchers, hunters and outfitters, and tribes in and near the BRWRA have experienced, and may continue to experience, negative social and economic impacts due to wolves, such as loss of revenue due to livestock depredation, fear for the safety of family members that may come into contact with wolves, stress due to the uncertainty of future economic losses wolves may cause, and anger at the government (Unsworth et al. 2005).

Given the recognition of the potential for social intolerance of wolves and human-caused sources of wolf mortality, past recommendations for Mexican wolves estimated suitable habitat to occur when human density is less than 12 people per square mile (2.56 km^2), with an optimum density of less than six people per square mile (Johnson et al. 1992). In keeping with these guidelines, the BRWRA was selected in part due to its low human population density (estimated at 0.8/mi^2 prior to the reintroduction) (USFWS 1996: Table 3-3).

Illegal take of wolves provides an indication of the level of social tolerance of the Mexican wolf reintroduction. In the BRWRA, illegal shooting of wolves has been the biggest single source of mortality since the reintroduction began in 1998. Illegal shootings have ranged from zero to seven per year between 1998 and July 2008 (USFWS 2008: Population Statistics). Out of 62 wild wolf mortalities documented in that timeframe, 28 deaths are attributed to illegal shooting (USFWS 2008: Population Statistics). Although AMOC attempts to address concerns about the reintroduction through outreach with affected citizens, management responsiveness, and education, these efforts have not been sufficient to alleviate some negative attitudes toward the Mexican wolf in the Southwest, nor has the independent depredation compensation program administered by Defenders of Wildlife, as evident by continued illegal shooting of wolves.

Individual sources of human-caused mortality are not independently evaluated in project statistics (AMOC and IFT: TC-6), thus the significance of all cases of human-caused mortality (illegal shooting, vehicle collision, capture-related deaths, legal shooting, lethal control) are evaluated as a whole. The loss rates (mortality and missing wolves) for the Blue Range population between 1998 and 2003 were similar to those predicted during planning stages (25 percent overall), and notably, have been lower than those documented in other wolf populations (AMOC and IFT 2005: TC-12, 17). Given that combined sources of mortality are in-line with project projections, this suggests that mortality from a single source (i.e., illegal take) is not a significant threat at its current levels.

However, the degree to which a wolf population is able to withstand a given level mortality depends on the population's productivity, including factors such as the level of reproduction, and whether breeding animals are killed (Fuller 1989, Fuller et al. 2003, Ballard et al. 1987, Ballard et al. 1997). A large range of values for the mean annual percentage of wolves killed by humans at levels that did not suppress population growth has been documented for wolf populations (Fuller et al. 2003). For example, in populations where habitat has been saturated and territorial conflicts between wolves result in wolf mortality, human-caused mortality may take the place of such conflicts (i.e., compensatory mortality). In these situations, wolves may be quite resilient to levels of human-caused mortality that are comparable to levels of mortality that would otherwise occur (Fuller et al. 2003). In the Great Lakes, illegal killing and vehicular collisions were significant sources of mortality for wolves, but were ultimately not deemed to be threats to recovery, as the populations continued to expand in number and range over time (72 FR 6051-6103, February 8, 2007). Similarly, human-caused mortality of over 20 percent per year of collared wolves in the Northern Rockies did not preclude the populations' abilities to expand in number and range (73 FR 10513-10560, February 27, 2008). A mortality rate of 0.34 has been estimated as the inflection point for wolf populations, with populations increasingly naturally when mortality rates are below this average and decreasing when mortality rates are above it (Fuller et al. 2003). The Mexican wolf could be more susceptible to population decline at a given mortality rate than other gray wolf populations, however, based on lower reproductive rates, smaller litter sizes, and combined sources of mortality (AMOC and IFT 2005: TC-17).

For example, the level of human-caused wolf mortality observed in the BRWRA becomes more significant when combined with removal of wolves for management purposes (e.g., boundary issues, cattle depredation, human nuisance, relocation, or pairing with another wolf), as these removals may have the same practical effect on the wolf population as mortality if the wolf is permanently removed (as opposed to translocated) -- that is, the population has one less wolf (see Paquet et al. 2001). Removal rates in the Blue Range population have been higher than projected in the FEIS, as have combined mortality/removal rates; from 1998-2003 the combined mortality/removal rate was 64 percent, as compared to a projection of 47% (AMOC and IFT 2005: 12-13). The number of wolf removals since the 5-Year Review has persisted at high levels, primarily due to livestock depredation response (USFWS 2008: Population Statistics). In 2007, the combined mortality/removal rate (i.e., failure rate) was 0.47, a level likely too high for unassisted population growth (AGFD et al. 2007).

Summary statement: Human-caused mortality of Mexican wolves, of which illegal shooting is a significant proportion, in combination with removal actions deemed necessary by management to address wolf conflicts, are hindering the population's growth toward the population objective of at least 100 wolves.

The Conservation Principles of Resiliency, Redundancy, and Representation

With several factors hindering the progress of the Blue Range population in achieving the objective of at least 100 wolves in the wild, the population is not as secure or self-sustaining as it could be. However, none of the threats are so significant as to put the population at immediate risk of extirpation. Even with a current assessment of the security of the Blue Range population in relation to the five factors, the degree to which this population contributes to gray wolf recovery is still unclear.

Consideration of the principles of *resiliency*, *redundancy*, and *representation* can help assess the contributions of the Blue Range population to recovery, although such an assessment is ultimately limited by the region's lack of objective and measurable recovery criteria. These principles represent a recently popularized conceptualization of key elements of biological diversity conservation (Shaffer and Stein 2000) and provide a useful framework for discussing scientific concepts relevant to gray wolf conservation, including demography, environmental variability, and genetics. The Service has invoked the principles of *resiliency*, *redundancy*, and *representation* to describe recovery efforts for the gray wolf in the Northern Rockies and Great Lakes (see 72 FR 6051-6103, February 8, 2007; 73 FR 10513-10560, February 27, 2008), and for consistency, the conservation assessment will use these principles in similar fashion. These principles were not originally coined for the purpose of guiding recovery efforts under the ESA, nor as a collective do they represent formal, peer-reviewed principles that establish any particular standard for conservation.

Summary statement: The Service has invoked the conservation principles of *resiliency*, *redundancy*, and *representation* to guide and communicate the fundamental components of wolf conservation and recovery.

Resiliency

Resiliency refers to a species' (or population's) ability to recover from disturbance and persist over time (Holling 1973). Gray wolves, as a species, have several characteristics that confer *resiliency*. First, their ability to use a variety of prey and habitat types helps to ameliorate fluctuations in food availability (Mech 1991, Weaver et al. 1996). Second, wolves are sometimes able to compensate for high levels of mortality with high levels of reproduction (although this has not necessarily been demonstrated by the Mexican wolf, see "Gray Wolf Biology and Ecology" and "Threats to the Gray Wolf in the Southwest: Factor E", above) (Weaver et al. 1996). Finally, wolves' ability to disperse long distances can result in demographic rescue; that is, a small or declining population can be bolstered by the arrival of immigrants (Brown and Kodric-Brown 1977).

As a principle for guiding general conservation efforts across taxa, *resiliency* suggests that species that are more numerous and widespread are more *resilient* than those that are not (Shaffer and Stein 2000). Thus, the *resiliency* of a species or population can be measured by its persistence (also referred to as viability, or conversely, extinction risk, thus these terms are used somewhat interchangeably depending on context). Because population size has a significant bearing on population persistence, consideration of *resiliency* can provide context for assessing the current reintroduction objective to establish a population of at least 100 wolves.

Scientific theory and practice generally agree that a species represented by a small population faces a higher risk of extinction than a species that is widely and abundantly distributed (Goodman 1987, Pimm et al. 1988). The primary cause of this susceptibility to extinction is the sensitivity of small populations to stochastic (that is, uncertain) demographic events (Shaffer 1987). That is, "The dynamics of a small population are governed by the specific fortunes of each of its few individuals. In contrast, the dynamics of a large population are governed by the law of averages (Caughley 1994:217)." Sex ratios, survival, and reproduction may all be affected by demographic stochasticity. For example, in a given year or series of years, offspring could be predominantly one gender or the other, fewer individuals may survive, or reproduction may be below average, causing random population fluctations. Even in a constant environment, the population trajectory for a small population will vary from year to year due to these events. In small populations, including those with a positive growth rate, it is more likely that a wide deviation from average birth or survival results could result in a decline toward extinction from which the population would not be able to recover (Mills 2007). Thus, as a population grows larger and individual events tend to average out, the population becomes less susceptible to demographic stochasticity. And, the higher the population growth rate, the more quickly persistence times will increase with increases in population size (Shaffer 1987). Population sizes considered "small" (that is, susceptible to demographic stochasticity) have been described as those that are less than 30 individuals, depending on age structure (Boyce 1992: 487), "on the order of 10s to 100s" (Shaffer 1987: 73), and over 100 (Mills 2007: 101). This being said, there is not a single population size that will ensure persistence (Thomas 1990). Rather, populations of various sizes, vital rates, and biological and ecological characteristics will simply have different risks of extinction.

A variety of methods are available for estimating a species' likelihood of persistence, ranging from complex theoretical or simulation models to simple observation of existing populations (Shaffer 1981) or best professional judgment (Mills 2007). Population viability analysis (PVA) and minimum viable population (MVP) analysis are tools that have been used in the past to develop numerical population targets for ESA recovery efforts (Clark et al. 2002). Both typically entail the use of complex theoretical or simulation models. Minimum viable population can be defined as the smallest population size required for a population to have a predetermined probability of persistence for a given length of time (Shaffer 1981). Minimum viable population has fallen out of favor in recent years, having been replaced with the closely related probabilistic approach of PVA (see Gilpin and Soule 1986, Beissinger and McCullough 2002). Population viability analysis is similar to MVP but simply does not require specification of a minimum population size to maintain the species' viability (Boyce 1992); rather, model output will describe the species' likelihood of persistence over a given timeframe, for example, that at a population size of 500, a species has a 12 percent risk of extinction over the next 50 years (Beissinger and McCoullough 2002).

The specification of extinction risk and timeframe are typically subjective in viability modeling efforts; there is no single set of values generally deemed acceptable within the scientific community to describe a (minimally) viable population (Allendorf and Luikart 2007), nor does the ESA equate any such numeric values with endangerment or recovery (Vucetich et al. 2006). Rather, individual bias, or perhaps situational limitations, influences whether a 5 or 10 percent level of risk or a 50 or 500-year timeframe is appropriate for a given viability exercise. For example, Shaffer (1981:132) defined a minimum viable population for any species as “the smallest isolated population having a 99 percent chance of remaining extant for 1,000 years despite the foreseeable effects of demographic, environmental, and genetic stochasticity, and natural catastrophes.”

Viability models can be tailored to consider questions about persistence based on information related to demography, genetics, management scenarios, or a host of other factors. Viability models developed to explore genetic issues (e.g., loss of diversity) may be quite different in structure and assumptions from models developed to explore demographic viability; for example, genetic PVAs may provide an effective population size opposed to a census (total) population size (see *Representation*, below). In some cases, models attempt to combine multiple kinds of information, such as genetics and demography, further contributing to their complexity. Although population viability analysis can provide powerful information when used appropriately, it is an intensive process with a number of shortcomings, including the subjective nature of determining appropriate extinction risk and time frame, time and cost necessary to gather adequate data, and the potential for results to be inappropriately applied in decision-making (Boyce 1992, Mills 2007: 252-265, Ewens et al. 1987, e.g., Patterson and Murray 2008).

Based on the above, it is not surprising that a brief literature review of wolf-specific population viability analyses and other estimations of wolf viability generate a range of results that can be difficult to compare. For example, Reed et al. (2003) incorporated age-structure, catastrophes, demographic stochasticity, environmental stochasticity, and inbreeding depression in an MVP analysis (99 percent probability of persistence for 40 generations) for a number of vertebrate species and recommended that minimum viable adult population size for the gray wolf was between approximately 1,400 and 6,300 wolves. Soule (1980) estimated an appropriate population size and area for short-term conservation for the gray wolf by incorporating data on wolf density, breeding structure, and carrying capacity, and recommended an absolute minimum effective population size of 100-200 wolves, or a census population size of at least 600 wolves and an area requirement of approximately 12,000 km^2, an area larger than Yellowstone National Park (Soule 1980:163). Viability analysis of the gray wolf on Isle Royale predicted a population of 50 wolves would have a mean time to extinction of 73 years, with a 30 percent chance of surviving over 100 years (Vucetich et al. 1997). Theoretical analysis of this population demonstrated that an increase in the number of breeding units increased the mean time to extinction due to demographic stochasticity more strongly than an increase in population size, suggesting that the social structure of wolves may increase their susceptibility to demographic stochasticity compared with species in which breeding units are not limited to the number of social (breeding) groups in the population.

Two viability analyses were conducted specific to the Mexican wolf prior to the reintroduction in 1990 and 1996, but neither was completed after being subject to peer review (IUCN 1996, Seal 1990). In both cases, data from extant Mexican wolf populations in the wild was unavailable, so information from other wild and captive wolf populations and the Mexican wolf captive population was used in modeling simulations to assess the effects of various reintroduction and management scenarios. The 1990 Mexican wolf PVA incorporated life history data, carrying capacity, environmental stochasticity, and inbreeding depression. Summary results found that populations of fewer than 50 wolves had a high risk of extinction but that populations of 100 or more wolves had a less than 5 percent probability of extinction over a 100-year time span (Seal 1990). The 1996 PVA, which incorporated similar types of information as the 1990 analysis, was specifically targeted toward the upcoming reintroduction of Mexican wolves into the Blue Range. This analysis found that the simulated Blue Range population experienced negative growth rates in scenarios with catastrophic events (i.e., drought) and had decreased viability in scenarios with inbreeding depression. Supplementation of the population of one adult pair of wolves and their offspring every 5 years virtually eliminated the risk of extinction during the 100-year time span, resulted in maintenance of population size around 100 wolves, and resulted in higher retention of genetic variation than in scenarios without management supplementation (although the model assumed that new individuals added to the population were unrelated to members of the existing population, which is unrealistic given the founding base of the captive population) (IUCN 1996).

Empirical observation of several wolf populations in North America and Europe demonstrates that populations of several dozen to several hundred animals are able to persist for several decades (Fritts and Carbyn 1995). This may lead to the conclusion that empirical data demonstrates persistence of wolf populations at sizes considerably smaller than those suggested viable by modeling efforts. However, the drawbacks of basing viability estimations strictly on empirical data are several, mainly that persistence in the past does not guarantee or provide a future time horizon for persistence, and that site-specific circumstances (such as environmental variability) may not be applicable to other situations.

Several approaches, often in combination, have been used by the Service to assess viability and extinction risk in listing and recovery efforts for the gray wolf, including utilization of formal population viability analyses (IUCN 1996), literature survey (USFWS 1994: Appendix 9), expert-panels and best professional judgment (USFWS 1994: Appendix 9; USFWS 2002a), and threat analysis (e.g., 72 FR 6051-6103, February 8, 2007; 73 FR 10513-10560, February 27, 2008).

For the gray wolf recovery program in the Northern Rockies, the Service developed and repeatedly reassessed recovery criteria based on best professional judgment. In the 1987 Northern Rocky Mountain Recovery Plan, which was developed by a recovery team, recovery criteria recommended establishment of a minimum of 10 breeding pairs for a minimum of 3 successive years in each of 3 core recovery areas, with connectivity between populations encouraged (USFWS 1987). These criteria were later revised based on literature survey, expert opinion, and best professional judgment, to 30 or more breeding pairs comprising some 300+ wolves in a metapopulation (a population that exists as partially isolated sets of subpopulations) with genetic exchange between subpopulations (USFWS 1994), in order to emphasize the importance of connectivity between populations. In the delisting of the Northern Rockies gray wolf distinct population segment, the Service acknowledged that the recovery criteria were likely a minimum standard for viability, supporting their position by pointing out that empirical evidence of wolf persistence demonstrates greater persistence than theory suggests (73 FR 10513-10560, February 27, 2008, and see Fritts and Carbyn 1995). In the Great Lakes gray wolf recovery program, recovery criteria specified the establishment of a Minnesota wolf population of 1,250-1,400 wolves, with establishment of a second population of either 100 wolves if located within 100 miles of the Minnesota population, or 200 wolves if located more than 100 miles from the Minnesota population demonstrating persistence for at least 5 years (USFWS 1992: 28). These criteria were also developed based on best professional judgment of viability by members of a recovery team. The only population target established in the Southwest is the reintroduction objective of establishing a population of more than 100 wolves, which although has not been considered a recovery criterion, was an estimation of viability based on the best professional judgment of the recovery team that wrote the 1982 Mexican Wolf Recovery Plan (USFWS 1982).

Noticeably, estimations of viability vary not only between previous gray wolf recovery plans but also between those recovery plans and the scientific literature. There may be several reasons for this variability, including site-specific considerations, advances in analytical techniques and data availability used to explore viability over the last 3 decades, and the range of perceived notions of viability that exist within the professional community relative to wolf conservation and the ESA.

Due to the large area requirements of wolves, area size is a feature of resiliency that is necessary to support viability. The area required to support a viable population depends on how a viable population is defined; clearly the area needed to support a population of several hundred wolves for several generations would be different than the area needed to support several thousand wolves for 100 or more years. Of equal importance, the area required to support a viable population would depend on the quality and configuration of habitat, with high quality habitat likely supporting a higher density of wolves than low quality habitat.

Area requirements for the wolf have been estimated to be in the range of 10,000-13,000 km^2 (4,000 to 5,000 mi^2) if the area is isolated from other populations (Mech, in Henshaw 1979:430 and Soulé 1980:163). The 1982 Mexican Wolf Recovery Plan estimated that a 5000 mi^2 area would be necessary to support a reintroduction objective of 100 wolves (USFWS 1982:23), which suggests that populations larger than 100 wolves may require areas in excess of 5,000 mi^2. In contrast, Isle Royale National Park in Lake Superior has supported a population of 12-50 wolves for 50 years in an area of just 210 mi^2 (538 km^2) (Wayne et al. 1991). Following a review of pertinent literature and wolf population case histories, Fritts and Carbyn (1995) concluded that areas as small as 3,000 km^2 (1158 mi^2), or even smaller, may be adequate to support a wolf population under near ideal circumstances (that is, abundant prey, a high level of tolerance for wolves by humans living in or using the area or adjacent areas, and effective legal protection); the wolf population that served as support for their conclusion ranged from 40-120 wolves over a 60 year period. Ideal conditions are rare, however, and population requirements extrapolated from demographic and genetic estimates of MVPs often require areas larger than available reserves (e.g., parks or designated wilderness areas) (Soule 1980:164). In such cases, it may be necessary to establish a network of habitat sites with interchange of wolves between areas to achieve an overall population target or degree of resiliency (Fritts and Carbyn 1995).

Effective recovery strategies in the Northern Rockies and Great Lakes gray wolf recovery programs have focused on establishing wolf populations in high quality core habitats surrounded by lower quality habitat supporting lower densities of prey and wolves. In the Southwest, lower prey densities due to the arid environment (Bednarz 1988) may necessitate larger areas to support a population of a given size compared with more productive habitat in the Northern Rockies or Great Lakes.

Summary statement: Results from existing gray wolf viability modeling efforts provide a wide range of population sizes, extinction probabilities, and time frames that do not collectively suggest a scientific consensus on what constitutes an appropriate degree of viability for gray wolf recovery pursuant to the ESA. Prior Service gray wolf recovery plans in the Great Lakes and Northern Rockies have estimated viable wolf populations as those that range from several hundred to over a thousand wolves.

Summary statement: The extinction risk of the current Blue Range population or the population target of at least 100 wolves is unknown because a current, complete, peer-reviewed viability analysis based on Mexican wolf data from the captive or Blue Range populations has not been conducted. Furthermore, the Service has not specified the viability (typically in the form of recovery criteria) that should be achieved for the gray wolf recovery program in the Southwest, including population size and area, acceptable probabilities of extinction risk, or time frame for persistence. Without these two pieces of information, it is not possible to evaluate the degree to which the current reintroduction establishes or contributes to resiliency for the Southwest.

Redundancy

Redundancy refers to the existence of redundant, or multiple, populations spread throughout a species' range. It addresses the adage, "Don't put all your eggs in one basket" and advances the notion that a species' likelihood of persistence generally increases with an increase in the number of sites it inhabits (Shaffer and Stein 2000). The need for redundancy is not a statement in support of the trade-off between establishing multiple, small populations over a single large population; rather it supports establishment and maintenance of multiple resilient populations as preferable to establishment and maintenance of one resilient population. That is, maintenance of multiple populations, rather than a single population, confers a benefit to the ability of a species to persist because it allows for populations to exist under different abiotic and biotic conditions, thereby providing a margin of safety that random perturbation (or, variation) affects only one, or a few, but not all, populations (Shaffer and Stein 2000). Thus, the principle of redundancy can be used to provide context for the establishment of a single wolf population in the Southwest.

Random variations in the environment that in turn affect the demography of a population are referred to as environmental stochasticity (Shaffer 1987). Environmental stochasticity, unlike demographic stochasticity, is not dependent on small population size and operates on populations of all sizes (Shaffer 1987, Mills 2007:103). Environmental stochasticity may take the form of variation in available resources (e.g., prey base), or in direct mortality (e.g., a disease epidemic), but either way results in variation in population growth rate (Shaffer 1987, Caughley 1994). Extreme environmental events, referred to as catastrophic, including events such as wildfire, drought, or a disease epidemic, may result in drastic, rapid population declines (Shaffer 1987). Consideration of environmental stochasticity would suggest that as the number of populations established increases, extinction risk of the species decreases.

The scientific literature does not recommend a specific number or range of populations appropriate for conservation efforts, although rule of thumb guidelines for the reintroduction of a species from captivity recommends that at least two populations be established that are demographically and environmentally independent (Allendorf and Luikart 2007: 472). Beyond this instruction, the need for redundancy is probably best described as a case-specific determination based on the conservation goal and the species' characteristics (e.g., longevity, dispersal behavior, mating structure). For a goal of recovering a species under the ESA, redundancy contributes to the recovery of a species such that it is no longer in danger of extinction throughout all or a significant portion of its range.

When a species is distributed in redundant populations, there are two possible relationships between the populations: they can be completely isolated from each other, or they can be connected with one another through the dispersal (also referred to as "migration" in the genetic literature) of individual animals. There are benefits and drawbacks to either relationship. For example, disease transmission will not occur between populations that are completely isolated from one another. However, immigration can bolster population size through arrival of new individuals (Brown and Kodric-Brown 1977), and if individuals successfully mate, can affect the genetic fitness of a population (Allendorf and Luikart 2007). If connectivity between populations is desired, conservation efforts must ensure that the distance between populations is compatible with wolf dispersal abilities and that the habitat through which individuals will be dispersing is of sufficient quality and quantity to support immigration. Alternatively, artificial immigration between populations must be accomplished through the translocation of wolves by management. Wolves generally have good dispersal ability through a variety of habitats, including heavily modified habitat (Fritts et al. 2003).

Support for redundancy as a feature of gray wolf recovery is provided by knowledge of historical gray wolf distribution patterns. Although some species are naturally distributed as endemics in a single or few localized populations, the gray wolf was historically widespread in North America in numerous populations connected by dispersal (including Mexican wolves in the Southwest and Mexico), supporting the conclusion that redundancy is a fundamental component of natural wolf distribution.

The necessity of establishing multiple populations has been central to the Service's gray wolf recovery programs in the Northern Rockies and Great Lakes. In both areas, the need for redundancy was examined within local circumstances, including habitat availability and connectivity, existing and desired levels of genetic diversity, and estimations of necessary demographic viability. In the Great Lakes, recovery criteria for delisting called for the establishment of two populations, explaining that:

> The requirement for more than a single recovery population stems from the basic concept of conservation biology that a species can never be assumed to be secure from extinction if only a single population exists…The only satisfactory means of reducing the threat of extinction…is to ensure that more than a single population is established prior to declaring the species recovered (USFWS 1992: 24).

Two populations, in this case, was considered minimally acceptable by the Eastern Timber Wolf recovery team at the time, although there was general agreement that additional populations would have provided increased security (USFWS 1992:24). In the Northern Rockies, gray wolf recovery criteria initially called for the establishment of three populations, later revised to require establishment of a metapopulation with genetic exchange between subpopulations. (USFWS 1987:10, USFWS 1994, USFWS 2002a).

In both the Great Lakes and Northern Rockies, connectivity between redundant populations has been an important consideration (USFWS 2002a, USFWS 1994). In the Great Lakes, the distance between the two populations, which determined the likelihood of (demographic and genetic) connectivity, influenced the population size deemed adequate for viability of the smaller population (USFWS 1992: 25). In the Northern Rockies, revised recovery criteria recommended connectivity via wolf dispersal between the three (sub)populations to ensure maintenance of genetic diversity in each subpopulation as well as the overall metapopulation (USFWS 1994, USFWS 2002a).

Numerous habitat assessments have been conducted to identify possible areas for reestablishment of the gray wolf in Arizona, New Mexico, Utah, Colorado, and Mexico. These studies, which are listed in chronological order, encompass a range of techniques and types of data and therefore as a collective provide only general insight as to the potential for redundancy in the Southwest.

Summary of Information on Four Potential Mexican Wolf Reintroduction Areas in Arizona
Johnson et al. (1992) compiled information on land area and ownership, precipitation, topography and vegetation, prey density, livestock use, competitors and predators, threatened and endangered species, human density, road density, future habitat alterations, and potential locations for pre-release acclimation enclosures in their analysis of four areas under consideration for Mexican wolf reintroduction in Arizona: the Blue Range Primitive Area, Chiricahua Mountains, Galiuro and Pinaleno Mountains, and Atascosa and Patagonia Mountains.

Colorado gray wolf recovery: a biological feasibility study
Bennett (1994) analyzed lands in Colorado designated as National Forests by the USDA-Forest Service, utilizing information on Forest area, percentage of public land of adjoining counties, mule deer and elk biomass, human density in adjoining county block, percentage of wilderness area in relation to National Forest area, road density, cattle density, level of recreational use, annual snowfall, and projected carrying capacity of wolves based on ungulate biomass. Seven areas were identified as "Potential Wolf Recovery Areas": Arapho-Roosevelt PWRA, Grand Mesa-Uncompahgre-Gunnison PWRA, Pike-San Isabel PWRA, Rio Grande PWRA, Routt PWRA, San Juan PWRA, and White River PWRA. Of these sites, all or portions of five sites were identified as good or satisfactory for wolf establishment, with issues related to livestock and human density being cited as primary deterrents in all or portions of four sites that would need to be addressed before reintroduction could be recommended.

Wolves in the Southern Rockies: report from the population and habitat viability workshop
Workshop participants assessed the suitability of 10 subregions within the Southern Rockies ecoregion for the reestablishment of wolf populations. Subregions were identified based on habitat factors such as prey abundance and availability, topography, land ownership, and road density. Viability predictions for each region were not finalized (Phillips et al. 2000).

The feasibility of gray wolf reintroduction to the Grand Canyon ecoregion
Sneed (2001) analyzed six biophysical and human-related factors to determine the feasibility of gray wolf reintroduction to the Arizona portion of the Grand Canyon: vegetation cover, surface water, ungulate prey abundance, human population density, road density, and land status. T he North Kaibab and the South Colorado Plateau were identified as potentially appropriate for establishment of the (Mexican) gray wolf.

Impacts of landscape change on wolf restoration success
Carroll et al. (2003) identified four potential reintroduction sites in the Southern Rocky Mountains Ecoregion (southern Wyoming, Colorado, and Northern New Mexico) with the ability to support gray wolf populations of varying sizes and extinction risk, based on habitat variables including vegetation, satellite imagery metrics, topography, climate, and human-impact and life history data. The sites included northern New Mexico, southwest Colorado, west-central Colorado, and northwestern Colorado. Projections for the year 2025, which took into account human population growth and resultant road development, generally demonstrated decreased carrying capacity of habitat and higher extinction risk of populations than current conditions.

Spatial analysis of restoration potential and population viability of the wolf (Canis lupus) in the southwestern United States and northern Mexico
Carroll et al. (2005) used life history data and habitat variables associated with vegetation, satellite imagery metrics, topography, climate, and human-impact to analyze five potential sites for gray wolf reestablishment in the southwestern United States (BRWRA in Arizona/New Mexico, Grand Canyon in Arizona, Mogollon Rim in Arizona, San Juans in Colorado, and Vermejo/Carson in northern New Mexico) and potential sites in Mexico (the Austin Ranch area located in Chihuahua/Sonora near the United States border, Carmen in

northern Coahuila, northwestern Durango, and the Tutuaca reserve area in westcentral Chihuahua) in order to predict the vulnerability of sites to landscape change. Scenarios included current conditions, future conditions in the year 2025 based on human population growth and landscape development. Results for the United States portion of the analysis demonstrated decreased carrying capacity of sites, decreased connectivity, and increased extinction risk over time due to landscape development.

Defining recovery goals and strategies for endangered species: the wolf as a case study
Carroll et al. (2006) analyzed potential wolf habitat across the western United States from the western edge of the Great Plains to the Pacific Ocean, using information on wolf life history, demography, and habitat variables (see Carroll et al. 2003). They specifically simulated reintroduction scenarios for the SWDPS (Arizona, New Mexico, western portions of Texas and Oklahoma, and southern portions of Colorado and Utah; see Status and Implications of National Gray Wolf Recovery for the Mexican Wolf, above) to identify and compare potential reintroduction sites now and projected for the year 2025. Four potential reintroduction sites were identified: Carson (Northern New Mexico), the Grand Canyon (Northern Arizona), the Mogollon Rim (central Arizona), and the San Juan Mountains (southwestern Colorado).

Summary statement: The number of redundant populations and related connectivity appropriate for recovery in the Southwest has not been specified; therefore the degree to which the Blue Range population contributes to redundancy cannot be determined.

Summary statement: Establishment of only a single Mexican wolf population in the Southwest provides the least amount of redundancy, and therefore the least amount of security from environmental perturbation, possible.

Summary statement: For a species that has been extirpated from so much of its historic range, explicit effort must be made to recreate redundancy.

Representation
Representation refers to the genetic diversity represented by members of a population or species, specifying that higher levels of diversity better support ecological and evolutionary processes than low (Shaffer and Stein 2000). *Representation* asserts that a species should be able to persist within the range of future habitat conditions that it may encounter (Shaffer and Stein 2000). Thus, *representation* allows for consideration of the short-term maintenance of fitness and vigor of individuals, and long-term maintenance of the species' adaptive potential (Soule 1980). *Representation* therefore provides context for considering the short and long-term genetic health of the captive and reintroduced Mexican wolf populations. On a much broader scale, *representation* also suggests that a species should be conserved in the variety of habitats in which it occurs in order to maintain the structure and function of ecosystems, i.e., ecosystem *representation* (Shaffer and Stein 2000). Although most conservation efforts under the ESA are directed at single-species, this level of representation aligns with one of the primary purposes of the statute, "to provide a means whereby the ecosystems upon which endangered species and threatened species may be conserved" 16 U.S.C 1531(b). Thus, both genetic and ecosystem *representation* will be considered.

Support for the appropriateness of genetic *representation* as a component of recovery stems from consideration of genetic stochasticity. Genetic stochasticity, commonly known as genetic drift, refers to the change in allele frequencies represented in a population from one generation to the next due to random mating events; genetic drift occurs in all natural populations (Allendorf and Luikart 2007). The degree of genetic drift experienced by a population is inversely related to its size; that is, greater changes in allele frequencies occur in small populations over time than in large, simply due to chance (Mills 2007). In small populations, attention to genetic structure and diversity may be a critical component of conservation efforts, although it has been argued that demographic events are likely to cause extinction before genetic concerns surface (Lande 1988).

Genetic drift results in a decrease in heterozygosity and an increase in homozygosity (Allendorf and Luikart 2007: 122), which can result in decreased individual fitness and decreased adaptive potential of the population (Allendorf and Luikart 2007, Franklin 1980, Soule 1980, Lande and Barrowclough 1987). Thus, the genetic effects of small population size can influence the persistence of a population through several outcomes, including loss of phenotypic variation, loss of adaptive potential, and the buildup of harmful mutations, including mitochondrial mutations (Allendorf and Ryman 2002). Small populations are also at greater risk of inbreeding depression (reduced fitness and vigor due to increased homozygosity or reduced heterozygosity resulting from the mating of related individuals) due to the smaller pool of unrelated potential mates available as compared to a larger population. Inbreeding depression may in some cases, but not all, affect traits that reduce population viability, such as reproduction, (Fredrickson et al. 2007) survival (Allendorf and Ryman 2002), or disease resistance (Hedrick et al. 2003). For animals such as the Mexican wolf for which complete pedigree information is available, the relationship between the degree of inbreeding and specific fitness traits can be analyzed to determine the severity of inbreeding (Asa et al. 2007, Fredrickson et al. 2007).

Importantly, it is the effective population size, rather than the census population size (as for demographic stochasticity), that primarily determines the rate of loss of heterozygosity, change in allele frequencies, and rate of inbreeding increase over time in a population (Waples 2002, and see Lande and Barrowclaugh 1987), and thus is a useful measure of *representation*. Effective population size is defined as "the size of the ideal population (N) that will result in the same amount of genetic drift as in the actual population being considered" (Allendorf and Luikart 2007: 148, also see Waples 2002: 149). Effective population size takes into account that not all members of a population reproduce every year; some may be too old, too young, not find a mate, or myriad other possibilities. Of those individuals that do mate, contributions to the next generation may differ due to an unequal sex ratio, number of offspring produced, survival of offspring, or other factors. To decrease the rate of genetic drift or likelihood of inbreeding (i.e., genetic stochasticity) experienced by a population, effective population size would have to increase (Mills 2007: 180).

For the gray wolf, social structure greatly affects which wolves mate. That is, in a population of 100 wolves, not all 100 wolves are reproductively active; rather, some proportion of those wolves will breed from year to year. Effective population size for the Mexican gray wolf has been estimated at 0.28 times the census population (range of 0.19 to 0.34) (USFWS 2002b,

USFWS 2003, USFWS 2004, USFWS 2005, USFWS 2006a, AGFD et al. 2007), which falls within the range of general estimates of effective population size for wildlife populations (0.2-0.3, see Mills 2007: 185). With a census population size of 100, effective population size would be about 28 wolves.

Several general (non-species specific) rules of thumb have been presented in the scientific literature to inform efforts for conservation of a species' or populations' genetic diversity. As with other estimations and recommendations of viability, these rules of thumb are not intended for verbatim application. The ESA does not require any particular level of genetic diversity as a component of recovery, rather genetic diversity is typically considered by Service in relation to threats or extinction risk depending on each species' circumstances.

Perhaps the most commonly cited genetically-based minimum viable population estimate is the 50/500 "rule" (Franklin 1980, Soule 1980), where the "50" represents a recommendation of the effective population size deemed adequate to maintain short-term fitness loss due to inbreeding (1 percent level of inbreeding per generation), and the "500" is the effective population size deemed adequate for the long-term maintenance of adaptive potential. These guidelines were developed as a general conservation recommendation for captive efforts based solely on genetic information without regard to other factors that may impact a species' long-term persistence (Mills 2007: 250). Lande and Barrowclaugh (1987) revisited the "500" recommendation, and concluded more generally that an effective population size of at least several hundred individuals would likely be necessary to maintain adaptive potential in most wildlife populations. Thomas (1990) suggested that a (census) population between 100 and 1,000 individuals would likely be adequate. Subsequently, Lande (1995) suggested that effective population sizes should be in the thousands based on the potential effects of mutation on population viability.

Determination of an appropriate effective population size (and extrapolation of a census population size) for conservation efforts may identify a population size that is too large for any one contiguous area to support. Thus, effective population size could adequately be achieved by establishing multiple populations that collectively total the necessary effective population size (Allendorf and Luikart 2007: 374). This situation would require specification of the level of connectivity needed between (sub)populations to ensure that genetic migration occurs. In other wolf populations, one migrant per generation (successfully reproducing) connectivity has been recommended (Allendorf 1983, Lande and Barrowclaugh 1987, Lacy 1987). This connectivity may present an opposing force to the potential for divergence of otherwise isolated populations stemming from natural selection and mutation (Allendorf and Luikart 2007:206).

The small number of wolves (seven animals, representing three lineages) the Mexican wolf captive breeding program was founded by has necessitated intensive management of genetic diversity as an integral component of the recovery effort. Management has focused on ensuring the representation of genes from each of the three founding lineages in both the captive and wild populations for both short-term and long-term genetic fitness. And, because there are no known remaining wild Mexican wolves that can be brought into captivity to increase the genetic diversity of the captive population, the continued maximization of overall gene diversity retention (avoidance of genetic drift) is critical for the future of the recovery program (Siminski and Spevak 2007).

The potential for inbreeding depression to occur in the Mexican wolf captive population has been a central concern of the breeding program. This concern led to the combination of the three founding lineages (McBride, Ghost Ranch, and Aragon) in 1995 following confirmation of the taxonomic standing of the lineages and recommendations that combining them would increase genetic variation (and thus, fitness) in the captive population (Hedrick et al. 1997). Representation of genes from the McBride lineage of wolves, which had been managed the longest under the SSP and were thought to be less heavily inbred than Ghost Ranch and Aragon wolves, was set at 80 percent for the captive population, with the remaining 20 percent being split evenly between the Ghost Ranch and Aragon lineages. Assuming positive results of merging the lineages became apparent, an increase to 25 percent representation for both the Ghost Range and Aragon lineages was deemed appropriate (Hedrick et al. 1997).

Several studies have been conducted to determine whether inbreeding depression exists and/or is resulting in decreased fitness in the captive and wild population of Mexican wolves. Initial study of the captive population found weak evidence of inbreeding depression (Kalinowski et al. 1999), but subsequent research documented inbreeding depression affecting body size (Fredrickson and Hedrick 2002). More recently, it has been found that inbreeding had little or no effect on captive wolves from the founding lineages as measured by the probability of producing live pups, litter size, and pup survival. However, crosses between pure-lineage captive wolves resulted in fitness increases in these traits, demonstrating genetic rescue due to the masking of deleterious alleles (Fredrickson et al. 2007). Inbreeding depression was observed in inbred cross-lineage captive wolves, suggesting the accumulation of deleterious or lethal alleles affecting these same traits (Fredrickson et al. 2007). In the reintroduced population, inbreeding depression has negatively affected litter sizes (Fredrickson et al. 2007). Fitness in these traits was affected in both male and female breeding wolves and pups. Lack of mating success in male wolves may be explained by subsequent documentation of inbreeding depression on sperm quality in pure-lineage Mexican wolves (Asa et al. 2007).

In addition to the management of the lineages, the SSP has focused on maintaining as much of the original gene diversity from the founding wolves as possible. The current gene diversity (83.05 percent of the founding population) in the Mexican wolf captive population is lower than similar captive breeding programs due to the small number of founders and a significant loss of genetic diversity from the management of the lineages prior to SSP involvement (Siminski and Spevak 2007). Conservation breeding programs typically strive to maintain at least 90 percent of the genetic diversity at the time of establishment to avoid the potential for lower birth weights, smaller litter sites, and greater neonatal mortality (Allendorf and Luikart 2007). According to the 2007 Species Survival Plan Population Analysis and Breeding Plan, the captive population will retain approximately 75 percent of its diversity over the next 44 years. Diversity will decrease to 66.12 percent after 100 years, unless carrying capacity of the captive facilities can be increased to allow for an increase in annual population growth rates of the population, which will improve genetic retention. Currently, the carrying capacity of the captive facilities is about 300 captive wolves, which has been reached by the existing population (Sivinski and Spevak 2007).

From a strict genetics perspective, the wild population should contain as much of the genetic diversity represented in the captive population as possible to avoid the potential for inbreeding and to maximize the ability of the Mexican wolf to adapt over time to changing environmental conditions. The goal of 80-10-10 ancestry of McBride, Aragon, and Ghost Ranch wolves in the captive population has been applied to the reintroduced population (Siminski and Spevak 2007), with the representation of the three lineages at 77.13 percent McBride, 12.9 percent Aragon, and 9.96 percent Ghost Ranch (as of July 28, 2007) (Siminski and Spevak 2007). In addition to the immediate fitness concerns related to inbreeding depression addressed by the merging of the founding lineages, it is also hoped that this strategy will maintain genetic diversity in support of the long-term adaptive potential of the Mexican wolf (Fredrickson et al. 2007). Results from genetic research demonstrate that additional release of cross-lineage wolves has the potential to increase the growth rate of the population and add genetic diversity to the current Blue Range population (Fredrickson et al. 2007); these releases have the greatest potential for effect at smaller population sizes, as the addition of just a few wolves into a small population will more significantly alter the ancestry represented than will those few releases into a large population. The overall genetic diversity of the Blue Range population of Mexican wolves (78.66 percent and 2.34 Founder Genome Equivalents, as of July 28, 2007) is lower than that of the captive population, which is expected given that the wild population was started using wolves that were well-represented in the captive population (Siminski and Spevak 2007).

Although genetic issues are recognized as a critically important component of the reintroduction, such issues must be balanced with other logistical considerations when wolves are being considered for release to the BRWRA. Wolves from the captive population are selected for release to the wild based on several factors, including their genetic makeup, reproductive performance, behavior, physical suitability, and overall response to the adaptation process in pre-release facilities (USFWS 2006a). Management of released wolves may not always fully support genetic considerations; for example, standard operating procedures may stipulate removal of a wolf because of its behavior, regardless of its genetic value to the population.

The recovery programs for the gray wolf in the Great Lakes and Northern Rockies provide minimal instruction for the application of genetic *representation* in the Southwest because their circumstances differ sufficiently from the Southwest. In both programs, connectivity among regional (sub)populations was an important consideration in the development of recovery criteria for the maintenance of genetic diversity (see USFWS 1992, USFWS 1994, USFWS 2002a). However, neither program has maintained a strict conservation focus on a subspecies of gray wolf as has the Southwest on the Mexican wolf, neither program has been dependent on a captive breeding program for reestablishment of wild populations, and both programs continue to depend in part on connectivity to large, healthy wolf populations in Canada for establishment, infusion, and maintenance of genetic diversity (72 FR 6051-6103, February 8, 2007; 73 FR 10513-10560, February 27, 2008).

There is some possibility in the future of immigration of wolves between regional recovery areas (e.g., a Northern Rockies wolf dispersing to the Southwest and breeding with a Mexican wolf), although this will depend in large part on future decisions related to delisting of the Great Lakes and Northern Rockies, modification of BRWRA boundaries, expansion of the Southwest's gray wolf recovery effort, state management, and future habitat conditions. This would present a new set of genetic considerations for the Southwest related to the purity of the Mexican wolf, inbreeding, and adaptive potential.

At the ecosystem level of *representation*, the Mexican wolf currently inhabits only the BRWRA, and therefore is not conserved in a variety of habitats. From the broader species perspective (rather than the subspecific Mexican wolf), gray wolves used to inhabit much of the Southwest, from its southern-most extent (and down into Mexico), up through the Southern Rockies, an area that included a variety of habitat types ranging from semi-desert grasslands to coniferous forests. Although the ESA does not mandate that a species be reestablished throughout its historic range or in all of the habitat types in which it historically occurred in order to achieve recovery, it does promote the conservation of ecosystems that support listed species. This factor, in combination with the potential for gray wolves to significantly alter the ecosystem structure of the areas they inhabit (see "Gray Wolf Biology and Ecology: Ecology and Habitat Description", above), lends credence to the consideration of ecosystem *representation* as a component of conservation and recovery efforts.

Collectively, the three regional gray wolf recovery programs achieve some degree of ecosystem *representation*, as they have resulted in the reestablishment of the gray wolf in a variety of significantly differing habitats in North America. However, given that the Service has not pursued gray wolf recovery at the national level, but rather at the regional level, the significance of this is difficult to evaluate. Prior gray wolf recovery plans in the Great Lakes and Northern Rockies did not include consideration of ecosystem *representation* as a component of recovery criteria, although the Service indirectly addressed ecosystem *representation* through the analysis of significance for delineation of both DPSs (72 FR 6059-6060, February 8, 2007; 73 FR 10520, February 27, 2008).

Summary statement: Short-term objectives for the appropriate balance of representation by each of the three founding lineages in the captive and reintroduced Mexican wolf populations have been determined and are actively being implemented through captive wolf pairings and selection of wolves for release to the wild. Maximization of long-term (several generations) genetic retention is a priority for the captive breeding program.

Summary statement: Determination of an effective population size or other genetic-related objectives appropriate for regional gray wolf recovery in the Southwest has not been made.

Summary statement: The degree to which ecosystem representation should be a component of conservation and recovery efforts in the Southwest is unclear based on minimal consideration of the concept by the Service in other gray wolf recovery efforts, nor has any determination of ecosystem representation been made for the Southwest. Without this information, the degree to which the Blue Range population contributes to regional representation cannot be evaluated.

CONCLUSION

The gray wolf recovery effort in the Southwest consists of an extensive international network of Mexican wolf captive breeding facilities and a single nonessential experimental population of Mexican wolves in Arizona and New Mexico. This two-pronged recovery strategy was the vision of the 1982 Mexican Wolf Recovery Plan, which has been the only gray wolf recovery plan developed for this region of the country. Although the 1982 recovery plan was instrumental in guiding the inception of the recovery effort, it no longer provides long-range guidance for the region. In particular, it established only a preliminary population objective for a single wolf population and does not contain recovery criteria.

Although the progress of the Blue Range population in achieving the population objective of at least 100 wolves has been more moderate than expected and has not yet been achieved, the population has steadily increased in size since wolves were initially released in 1998. Intensive management provides considerable security that any specific threat as discussed herein does not likely pose an immediate extinction risk to the population due to the existence of over 300 wolves in captivity and the ability of management to bolster the Blue Range population with captive wolves in response to a major population decline or noticeable decline in fitness. However, individual threats (including aspects of the current management regime), and more so the combination of threats, still have the potential to decrease population size and growth rate, causing it to remain at a level at which it is more susceptible to stochastic events and to further hinder progress toward the population objective to establish a population of at least 100 wolves.

Without a current recovery plan that addresses gray wolf recovery in the Southwest, the role of the Blue Range population in the regional recovery effort is unstated, although clearly significant. The intent of the ESA is to recover species such that they are able to sustain themselves in the wild. A "recovered" species is not one that has a zero chance of extinction; rather, it has a risk of extinction that is deemed acceptable for Federal protections to be removed with a high degree of certainty that the species is and will continue to be self-sustaining in the wild. Although some degree of management intervention may be necessary after delisting for a wide-ranging, socially controversial predator such as the wolf, such intervention should serve to make minor adjustments when necessary within a reasonable range of population fluctuation, not serve as a major hedge against extinction.

Application of the conservation principles of *resiliency*, *redundancy*, and *representation* provide insight into the contributions of the Blue Range reintroduction project to gray wolf recovery in the Southwest. Exploration of demographic stochasticity (*resiliency*) suggests that a population of more than 100 wolves will have less extinction risk than a population of less than 100 wolves, exploration of environmental stochasticity (*redundancy*) suggests that establishment of more than one population further lessens extinction risk for the Mexican wolf by providing safety from environmental perturbations, and exploration of genetic stochasticity (*representation*) suggests that short-term fitness and long-term adaptive potential of a population is best supported by establishing larger, rather than smaller, effective population sizes. Ecosystem *representation* suggests that the distribution of the gray wolf in a variety of habitats in the Southwest is an important consideration for ecosystem diversity. Thus, although the contributions of the Blue Range population to *resiliency*, *redundancy*, and *representation* are ultimately limited by a lack of objective and measurable recovery criteria against which the population objective to establish a single population of at least 100 wolves can be evaluated, it is clear that establishment of a single population of at least 100 wolves does not achieve *resiliency*, *redundancy*, or *representation*.

These principles have provided guidance for the agency's gray wolf recovery efforts in the Great Lakes and Northern Rockies, and as such provide a useful framework for structuring continuing gray wolf recovery efforts in the Southwest. *Resiliency*, *redundancy*, and *representation* are somewhat interdependent, meaning that the degree to which one is realized may affect and in turn be affected by the degree to which the others are realized. For example, *representation* may be affected by the number and connectivity of disjunct populations (*redundancy*), thus *redundancy* may be necessary not only to address environmental variability, but also to achieve appropriate levels of *representation*. This flexibility may be beneficial for application to recovery efforts because it allows for trade-offs to be made based on site-specific considerations to ensure effective implementation of conservation actions. Simply put, these principles support a range of appropriate formulations for gray wolf recovery.

The ecological, social, and economic landscape of the Southwest creates a unique backdrop for gray wolf recovery efforts, and certainly scientific determinations of *resiliency*, *redundancy*, and *representation* will be accompanied by considerations of social and economic factors. Moreover, resolution of litigation and policy decisions will continue to shape recovery efforts at the regional and national level. However, given the substantial progress in securing the Mexican wolf from extinction that has been made over the last 30 years, it is time to shift the focus of the recovery program from "brink of extinction" toward a program in pursuit of recovery.

LITERATURE CITED

Adaptive Management Oversight Committee and Interagency Field Team [AMOC and IFT]. 2005. Mexican wolf Blue Range reintroduction project 5-year review. Unpublished report to U.S. Fish and Wildlife Service, Region 2, Albuquerque, New Mexico, USA. http://www.fws.gov/southwest/es/mexicanwolf/MWNR_FYRD.shtml

Allendorf, F.W., and G. Luikart, editors. 2007. Conservation and the genetics of populations. Blackwell, Malden, Massachusetts, USA.

Allendorf, F.W., and N. Ryman. 2007. The role of genetics in population viability analysis. Pages 50-85 *in* Allendorf F.W., and G. Luikart, editors. Conservation and the genetics of populations. Blackwell, Malden, Massachusetts, USA.

Allendorf, F.W. 1983. Isolation, gene flow, and genetic differentiation among populations. Pages 51-65 *in* Schonewald-Cox C.M., S.M. Chambers, B. MacBryde, L. Thomas, editors. Genetics and conservation. Benjaim/Cummings, Menlo Park, California, USA.

Arizona Department of Health Services [AZDHS]. 2008. Rabies statistics and maps website. < http://azdhs.gov/phs/oids/vector/rabies/stats.htm>. Accessed August 18, 2008.

Arizona Game and Fish Department [AGFD]. 2008. Mexican wolf reintroduction and management website. < http://www.azgfd.gov/w_c/es/wolf_reintroduction.shtml>. Accessed July 29, 2008.

Arizona Game and Fish Department [AGFD], and New Mexico Department of Game and Fish [NMDGF]. 2002. Arizona-New Mexico review of the U.S. Fish and Wildlife Service's 3-year review of the Mexican wolf reintroduction project. Final, September 30, 2002.

Arizona Game and Fish Department [AGFD], New Mexico Department of Game and Fish, U.S. Department of Agriculture - Animal and Plant Health Inspection Service - Wildlife Services, U.S. Fish and Wildlife Service, and White Mountain Apache Tribe. 2007. Mexican wolf Blue Range reintroduction project: interagency field team report (reporting period January 1-December 31, 2007).

Asa, C., P. Miller, M. Agnew, J.A.R. Rebolledo, S.L. Lindsey, M. Callahan, and K. Bauman. 2007. Relationship of inbreeding with sperm quality and reproductive success in Mexican wolves. Animal Conservation 10:326-331.

Association of Zoos and Aquariums [AZA]. 2008. AZA website. <http://www.aza.org/HonorsAwards/NA_Multiple/index.html>. Accessed May 20, 2008.

Ballard, W.B., L.A. Ayers, P.R. Krausman, D.J. Reed, and S.G. Fancy. 1997. Ecology of wolves in relation to a migratory caribou herd in northwest Alaska. Wildlife Monographs 135:1-47.

Ballard, W.B., L.N. Carbyn, and D.W. Smith. 2003. Wolf interactions with non-prey. Pages 259-271 *in* Mech L.D., L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

Ballard, W.B., and P.S. Gipson. 2000. Wolf. Pages 321-346 *in* Demarais S., and P.R. Krausman, editors. Ecology and management of large mammals in North America. Prentice Hall, Upper Saddle River, New Jersey, USA.

Ballard, W.B., J.S. Whitman, and C.L. Gardner. Ecology of an exploited wolf population in south-central Alaska. 1987. Wildlife Monographs 98:1-54.

Bangs, E. 2002. Wolf population viability peer review – draft summary. Unpublished report to U.S. Fish and Wildlife Service, Region 6, Helena, Montana, USA.

Bangs, E.E., J. Fontaine, T. Meier, C. Niemeyer, M. Jimenez, D. Smith, C. Mack, and V. Asher, L. Handegard, M. Collinge, R. Krischke, C. Sime, S. Nadeau, and D. Moody. 2004. Restoration and conflict management of the gray wolf in Montana, Idaho and Wyoming. Transactions of the North American Wildlife and Natural Resources Conference 69:89-105.

Bednarz, J.C. 1988. The Mexican wolf: biology, history, and prospects for reestablishment in New Mexico. Endangered Species Report Number 18. U.S. Fish and Wildlife Service, Region 2, Albuquerque, New Mexico, USA.

Beissinger, S.R., and D.R. McCoullough. 2002. Population viability analysis. University of Chicago Press, Chicago, Illinois, USA.

Bennet, L.E. 1994. Colorado gray wolf recovery: a biological feasibility study. Final report – March 31, 1994. U.S Fish and Wildlife Service, Region 6, Denver, Colorado, and University of Wyoming Fish and Wildlife Cooperative Research Unit, Laramie, Wyoming, USA.

Bogan, M.A., P. Mehlhop. 1980. Systematic relationship of gray wolves (*Canis lupus)* in Southwestern North America. National Fish and Wildlife Laboratory, Washington, and University of New Mexico, Albuquerque, New Mexico, USA.

Bogan, M.A., and P. Mehlhop. 1983. Systematic relationships of gray wolves (*Canis lupus)* in southwestern North America. Occasional Papers of the Museum of Southwestern Biology 1:1-20.

Boitani, L. 2003. Wolf conservation and recovery. Pages 317-340 *in* Mech L.D., and L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

Boutin, S. 1992. Predation and moose population dynamics: a critique. Journal of Wildlife Management 56:116-127.

Boyce, M.S. 1992. Population viability analysis. Annual Review of Ecology and Systematics 23:481-506.

Bradley, E.H., and D.H. Pletscher. 2005. Assessing factors related to wolf depredation of cattle in fenced pastures in Montana and Idaho. Wildlife Society Bulletin 33(4): 1256-1265.

Brewster, W.G., and S.H. Fritts. 1995. Taxonomy and genetics of the gray wolf in Western North America: a review. Pages 353-373 *in* Carbyn, L.N., S.H. Fritts, and D.R. Seip. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, Occasional Publication No. 35. University of Alberta, Edmonton, Alberta, Canada.

Brook, B.W., L.W. Traill, and C.A.J. Bradshaw. 2006. Minimum viable population sizes and global extinction risk are unrelated. Ecology Letters 9:375-382.

Brown, D.E. 1983. The wolf in the Southwest: the making of an endangered species. The University of Arizona Press, Tucson, Arizona, USA.

Brown, J.H., and A. Kodric-Brown. 1977. Turnover rates in insular biogeography: effect of immigration on extinction. Ecology 58:445-449.

Brown, W.M., and D.R. Parsons. 2001. Restoring the Mexican gray wolf to the mountains of the Southwest. Pages 169-186 *in* Maehr, D.S., R.F. Noss, and J.L. Larkin, eds. Large mammal restoration, ecological and sociological challenges in the 21st Century. Island Press, Washington, D.C.

Carrera, R., W. Ballard, P. Gipson, B.T. Kelly, P.R. Krausman, M.C. Wallace, C. Villalobos, D.B. Wester. 2008. Comparison of Mexican wolf and coyote diets in Arizona and New Mexico. Journal of Wildlife Management 72(2):376-381.

Carroll, C., M.K. Phillips, and C.A. Lopez-Gonzalez. 2005. Spatial analysis of restoration potential and population viability of the wolf (*Canis lupus)* in the southwestern United States and northern Mexico. Klamath Center for Conservation Research, Orleans, California, USA. (2 December 2005; www.klamathconservation.org)

Carroll, C., M.K. Phillips, C.A. Lopez-Gonzalez, and N.A. Schumaker. 2006. Defining recovery goals and strategies for endangered species: the wolf as a case study. Bioscience 56(1):25-37.

Carroll, C., M.K. Phillips, N.H. Schumaker, and D.W. Smith. 2003. Impacts of landscape change on wolf restoration success: planning a reintroduction program based on static and dynamic spatial models. Conservation Biology 17:536-548.

Carroll, C., R.F. Noss, and P.C. Paquet. 2001. Carnivores as focal species for conservation planning in the Rocky Mountain region. Ecological Applications 11:961-980.

Caughley, G. 1994. Directions in conservation biology. The Journal of Animal Ecology 63:215-244.

Clark, J.A., J.M. Hoekstra, P.D. Boersma, and P. Kareiva. 2002. Improving U.S. Endangered Species Act recovery plans: key findings and recommendations of the SCB recovery plan project. Conservation Biology 16:1510-1519.

Duda, M.D., and K.C. Young. 1995. Public opinion on and attitudes toward fish and wildlife management: New Mexico residents' opinions toward Mexican wolf reintroduction. Responsive Management, Harrisonburg, Virginia, USA.

Ewens, W.J., P.J. Brockwell, J.M. Gani, and S.I. Resnick. 1987. Minimum viable population size in the presence of catastrophes. Pages 59-68 *in* Soule, M.E., editor. Viable populations for conservation. Cambridge University Press, Cambridge, UK.

Franklin, I.R. 1980. Evolutionary change in small populations. Pages 135-149 *in* Soule, M.E., and B.A Wilcox, editors. Conservation biology: an evolutionary-ecological perspective. Sinauer Associates, Sunderland, Massachusetts, USA.

Fredrickson, R.J., and P.W. Hedrick. 2002. Body size in endangered Mexican wolves: effects of inbreeding and cross-lineage matings. Animal Conservation 5:39-43.

Fredrickson, R.J., P. Siminski, M. Woolf, and P.W. Hedrick. 2007. Genetic rescue and inbreeding depression in Mexican wolves. Proceedings of the Royal Society B 274: 2365-2371.

Fritts, S.H., and L.N. Carbyn. 1995. Population viability, nature reserves, and the outlook for gray wolf conservation in North America. Restoration Ecology 3:26-28.

Fritts, S.H., and L.D. Mech. 1981. Dynamics, movements and feeding ecology of a newly protected wolf population in northwestern Minnesota. Wildlife Monographs 80:1-79.

Fritts, S.H., W.J. Paul, and L.D. Mech. 1984. Movements of translocated wolves in Minnesota. Journal of Wildlife Management 48(3):709-721.

Fritts, S.H., R.O. Stephenson, R.D. Hayes, and L. Boitani. 2003. Wolves and humans. Pages 289-316 *in* Mech, L.D., and L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

Fuller, T.K. 1989. Population dynamics of wolves in north-central Minnesota. Wildlife Monographs 105:1-41.

Fuller, T.K. 2004. Wolves of the world. Voyageur Press, Stillwater, Minnesota, USA.

Fuller, T.K. 2003. Wolf population dynamics. Pages 161-191 *in* Mech, L.D., and L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

García-Moreno, J., M.D. Matocq, M.S. Roy, E. Geffen, and R.K. Wayne. 1996. Relationships and genetic purity of the endangered Mexican wolf based on analysis of microsatellite loci. Conservation Biology 10(2): 376-387.

Gasaway, W.E., R.D. Boertje, D.V. Grangaard, D.B. Kelleyhouse, R.O. Stephenson, and D.G. Larsen. 1992. The role of predation in limiting moose at low densities in Alaska and Yukon and implications for conservation. Wildlife Monographs, Number 120. The Wildlife Society, Bethesda, Maryland, USA.

Gilpin, M.E., and M.E. Soule. 1986. Minimum viable populations: processes of species extinction. Pages 19-34 in Soule, M.E., editor. Conservation biology: the science of scarcity and diversity. Sinauer Associates, Sunderland, Massachusetts, USA.

Gipson, P.S., and W.B. Ballard. 1998. Accounts of famous North American wolves, *Canis lupus.* The Canadian Field Naturalist 112:724-739.

Gipson, P.S., W.B. Ballard, and R.M. Nowak. 1998. Famous North American wolves and the credibility of early wildlife literature. Wildlife Society Bulletin 26(4):808-816.

Goodman, D. 1987. The demography of chance extinction. Pages 11-31 *in* Soule, M.E. editor. Viable populations for conservation. Cambridge University Press, Cambridge, UK.

Hall, E.R., and K.R. Kelson. 1959. The mammals of North America, Volume II. The Ronald Press, New York, New York, USA.

Hall, E.R. 1981. The mammals of North America. 2 volumes. John Wiley and Sons, New York, New York, USA.

Harrington, F.H., and L.D. Mech. 1983. Wolf pack spacing: howling as a territory-independent spacing mechanism in a territorial population. Behavioral Ecology and Sociobiology 12:161-168.

Hedrick, P.W., and S.T. Kalinowski. 2000. Inbreeding depression in conservation biology. Annual Review of Ecology and Systematics 31:139-216.

Hedrick, P.W., R.N. Lee, and K.M. Parker. 2000. Major histocompatibility complex (MHC) in the endangered Mexican wolf and related canids. Heredity 85(6):617-624.

Hedrick, P.W., P.S. Miller, E. Geffen, and R.K. Wayne. 1997. Genetic evaluation of the three captive Mexican wolf lineages. Zoo Biology 16:47-69.

Hedrick, P.W., R.N. Lee, and C. Buchanan. 2003. Canine parvovirus enteritis, canine distemper, and Major Histocompatibility Complex genetic variation in Mexican wolves. Journal of Wildlife Diseases 39(4):909-913.

Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Review Ecology and Systematics 4:1-23.

Husseman, J.S., D.L. Murray, G. Power, C. Mack, C.R. Wenger, and H. Quigley. 2003. Assessing differential prey selection patterns between two sympatric large carnivores. OIKOS 101:591-601.

International Union for Conservation of Nature [IUCN]. 1996. Mexican wolf population viability analysis draft report. Sponsored by the Conservation Breeding Specialist Group, Apple Valley, Minnesota, USA.

International Wolf Center [IWC]. 2008. IWC website. <http://www.wolf.org/wolves/news/live_news_detail.asp?id=1340>. Accessed March 24, 2008.

Johnson, T.B., D.C. Noel, and L.Z. Ward. 1992. Summary of information on four potential Mexican wolf reintroduction areas in Arizona. Technical Report 23. Arizona Game and Fish Department, Phoenix, Arizona, USA.

Kalinowski, S.T., P.W. Hedrick, and P.S. Miller. 1999. No inbreeding depression observed in Mexican and red wolf captive breeding programs. Conservation Biology 13: 1371-1377.

Kellert, S.R. 1985. Public perceptions of predators, particularly the wolf and coyote. Biological Conservation 31:167-189.

Kelly, B., M. Brown, and O. Byers (eds). 2001. Mexican wolf reintroduction program three-year review workshop: final report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN.

Kreeger, T.J. 2003. The internal wolf: physiology, pathology, and pharmacology. Pages 192-217 *in* Mech, L.D., and L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

Kunkel, K.E., T.K. Ruth, D.H. Pletscher, M.G. Hornocker. 1999. Winter prey selection by wolves and cougars in and near Glacier National Park, Montana. Journal of Wildlife Management 63(3):901-910.

Lacy, R.C. 1987. Loss of genetic diversity from managed populations: interacting effects of drift, mutation, immigration, selection, and population subdivision. Conservation Biology 1: 143-158.

Laikre, L., and N. Ryman. 1991. Inbreeding depression in a captive wolf (*Canis lupus*) population. Conservation Biology 5:33-40.

Lande, R.L. 1988. Genetics and demography in biological conservation. Science 241:1455-1460.

Lande, R.L. 1995. Mutation and Conservation. Conservation Biology 9:782-791.

Lande, R.L. and G.F. Barrowclough. 1987. Effective population size and genetic variation. Pages 87-123 i*n*, Soule, M.E., editor. Viable populations for conservation. Cambridge University Press, Cambridge, UK.

Leonard, J.A., C. Vilá , and R.K. Wayne. 2005. Legacy lost: genetic variability and population size of extirpated US grey wolves (*Canis lupus*). Molecular Ecology 14:9-17.

Lindsey, S.L., and P. Siminski. 2007. The return of the lobo: a binational success story. Association of Zoos and Aquariums [AZA] Publication. January 2007. AZA website. <http://www.aza.org/Publications/2007/01/return_lobo.pdf>.

McBride, R.T. 1980. The Mexican wolf (*Canis lupus baileyi*): a historical review and observations on its status and distribution. Endangered Species Report 8: U.S. Fish and Wildlife Service, Region 2, Albuquerque, New Mexico, USA.

McNay, M.E. 2002. Wolf-human interactions in Alaska and Canada: a review of the case history. Wildlife Society Bulletin 30(3):831-843.

Mech, L.D. 1991. The Way of the Wolf. Voyageur Press, Stillwater, Minnesota, USA.

Mech, L.D. 1989. Wolf population survival in an area of high road density. American Midland Naturalist 121:387-389.

Mech, L.D. 1988. Longevity in wild wolves. Journal of Mammology 69:197-198.

Mech, L.D. 1970. The wolf: the ecology and behavior of an endangered species. The Natural History Press, Garden City, New York, USA.

Mech, L.D, and L. Boitani. 2003. Wolf social ecology. Pages 1-34 *in* Mech, L.D., L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

Mech, L.D., S.H. Fritts, G.L. Radde, W.J. Paul. 1988. Wolf distribution and road density in Minnesota. Wildlife Society Bulletin 16(1):85-87.

Mech, L.D., E.K. Harper, T.J. Meier, and W.J. Paul. 2000. Assessing factors that may predispose Minnesota farms to wolf depredations on cattle. Wildlife Society Bulletin 28(3): 623-629.

Mech, L.D., and R.O. Peterson. 2003. Wolf-Prey Relations. Pages 131-160 *in* Mech, L.D., Boitani L, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

Mech, L.D., and U.S. Seal. 1987. Premature reproductive activity in wild wolves. Journal of Mammology 68(4):871-873.

Messier F. 1985. Solitary living and extra-territorial movements of wolves in relation to social status and prey abundance. Canadian Journal of Zoology 63:239-45.

Messier, F. 1994. Ungulate population models with predation: a case study with the North American moose. Ecology 75:478-88.

Mills, L.C. 2007. Conservation of wildlife populations: demography, genetics, and management. Blackwell Publishing, Malden, Massachusetts, USA.

Mladenoff, D.J., T.A. Sickley, R.G. Haight, and A.P. Wydeven. 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes region. Conservation Biology 9: 279-294.

Nowak, R.M. 1995. Another look at wolf taxonomy. Pages 375-397 *in* Carbyn, L.N., S.H. Fritts, and D.R. Seip. Ecology and conservation of wolves in a changing world. Occasional Publication No. 35. Canadian Circumpolar Institute, Univeristy of Alberta, Edmonton, Alberta, Canada.

Nowak, R.M. 2003. Wolf evolution and taxonomy. Pages 239-258 *in* Mech, L.D., and L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

O'Grady, J.J., B.W. Brook, D.H. Reed, J.D. Ballou, D.W. Tonkyn, and R. Frankham. 2006. Realisitic levels of inbreeding depression strongly affect extinction risk in wild populations. Biological Conservation 133:42-51.

Oakleaf, J.K., C. Mack, and D.L. Murray. 2003. Effects of wolves on livestock calf survival and movements in central Idaho. Journal of Wildlife Management 67(2):299-306.

Packard, J.M. 2003. Wolf behavior: reproductive, social, and intelligent. Pages 35-65 *in* Mech, L.D., L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

Packard, J.M., L.D. Mech, U.S. Seal. 1995. Social influences on reproduction in wolves. Pages 78-85 *in* Carbyn, L.N., S.H. Fritts, and D.R. Seip. Ecology and conservation of wolves in a changing world. Occasional Publication No. 35. Canadian Circumpolar Institute, University of Alberta, Edmonton, Alberta, Canada.

Paquet, P.C., J.A.Vucetich, M.K. Phillips, and L.M. Vucetich. 2001. Mexican wolf recovery: three-year program review and assessment. Prepared by the Conservation Breeding Specialist Group for the United States Fish and Wildlife Service, Albuquerque, New Mexico. Apple Valley, Minnesota, USA.

Parsons, D. 1996. Case study: the Mexican wolf. Pages 101-123 *in* Herrera, E.A., L.F. Huenneke, editors. New Mexico's natural heritage: biological diversity in the Land of Enchantment. New Mexico Journal of Science 36.

Parsons, D.R. 1998. 1998 Mexican wolf interagency management plan. U.S. Fish and Wildlife Service, Albuquerque, New Mexico, USA.

Parsons, D.R., and J.E. Nicholopoulos. Status of the Mexican wolf recovery program in the United States. Pages 141-146 *in* Carbyn, L.N., S.H. Fritts, and D.R. Seip. Ecology and conservation of wolves in a changing world. Occasional Publication No. 35. Canadian Circumpolar Institute, University of Alberta, Edmonton, Alberta, Canada.

Patterson, B.R. and D.L. Murray. 2008 in press. Flawed population viability analysis can result in misleading population assessment: a case study for wolves in Algonquin park, Canada. Biological Conservation. doi:10.1016/j.biocon.2007.12.010.

Peters, R.P., and L.D. Mech. 1975. Scent-marking in wolves. American Scientist 63:628-637.

Peterson, R.O., and P. Ciucci. 2003. The wolf as a carnivore. Pages 104-130 *in* Mech, L.D., and L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

Phillips, M.K., N. Fasicione, P. Miller, and O. Byers. 2000. Wolves in the Southern Rockies. A population and habitat viability assessment: final report. International Union of Concerned Scientists, Conservation Breeding Specialist Group, Apple Valley, Minnesota, USA.

Phillips, M.K, V.G. Henry, B.T. Kelly. 2003. Restoration of the red wolf. Pages 272-288 *in* Mech, L.D., and L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

Pimm, S.L., H.L. Jones, and J. Diamond. 1988. On the risk of extinction. The American Naturalist 132:757-785.

Primm, S.A., and T.W. Clark. 1996. Making sense of the policy process for carnivore conservation. Conservation Biology 10(4):1036-1045.

Reed, D.H., J.J. O'Grady, B.W. Brook, J.D. Ballou, R. Frankham. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation 111:23-34.

Reed, J.E., W.B. Ballard, P.S. Gipson, B.T. Kelly, P.R. Krausman, M.C. Wallace, D. B. Wester. 2006. Diets of free-ranging Mexican gray wolves in Arizona and New Mexico. Wildlife Society Bulletin 34(4):1127-1133.

Reed, D.H., J.J. O'Grady, B.W. Brook, J.D. Ballou, and R. Frankham. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation 113: 23-34.

Research and Polling, Incorporated. 2008. Wolf recovery survey: Arizona and New Mexico. Albuquerque, New Mexico, USA. http://www.rpinc.com/wb/pages/rpi.php.

Rodriquez, M., P.R. Krausman, W.B. Ballard, C. Villalobos, and W.W. Shaw. 2003. Attitudes of Mexican citizens about wolf translocation in Mexico. Wildlife Society Bulletin 31(4):971-979.

Ripple, W.J., and R.L. Becsheta. 2004. Wolves, elk, willows, and trophic cascade in the upper Galatin Range of southwestern Montana. Forest Ecology and Management 200:161-181.

Ripple, W.J., and R.L. Becsheta. 2003. Wolf reintroduction, predation risk, and cottonwood recovery in Yellowstone National Park. Forest Ecology and Management 184: 299-313.

Rothman, R.J., and L.D. Mech. 1979. Scent-marking in lone wolves and newly formed pairs. Animal Behavior 27:750-760.

Roy, M.S., E. Geffen, D. Smith, E.A. Ostrander, R.K. Wayne. 1994. Patterns of differentiation and hybridization in North American wolflike canids, revealed by analysis of microsatellite loci. Molecular Biology and Evolution 11(4):553-570.

Seal, U.S. 1990. Mexican wolf population viability assessment: Review draft report of workshop. 22-24 October 1990. Sponsored by International Union for Conservation of Nature, Conservation Breeding Specialist Group. Fossil Rim Wildlife Center, Glen Rose, Texas, USA.

Secretaría de Medio Ambiente, Recursos Naturales y Pesca [SEMARNAP]. 2000. Proyecto de recuperación del lobo mexicano (*Canis lupus baileyi*). Instituto Nacional de Ecología. Tlacopac, San Ángel, México, D.F.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. BioScience 31:131-134.

Shaffer, M.L. 1987. Minimum viable populations: coping with uncertainty. Pages 69-86 *in* Soule, M.E. editor. Viable populations for conservation. Cambridge University Press, New York, New York, USA.

Shaffer, M.L., and B.A. Stein. 2000. Safeguarding our precious heritage. Pages 301-321 *in* Stein, B.A., L.S. Kutner, J.S. Adams. Precious heritage: the status of biodiversity in the United States. Oxford University Press, City, State/Country.

Siminski, D.P. 2005. Mexican wolf, *Canis lupus baileyi*, international studbook. The Living Desert, Palm Desert, California, USA.

Siminski, D.P., and E.M. Spevak. 2007. Mexican wolf (*Canis lupus baileyi*) species survival plan: population analysis and breeding plan. Technical Report. The Living Desert, Palm Desert, California, USA.

Sneed, P.G. 2001. The feasibility of gray wolf reintroduction to the Grand Canyon ecoregion. Endangered Species Update:18(4):153-158.

Soule, M.E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-169 *in* Soule, M.E., and B.A. Wilcox BA, editors. Conservation biology: an evolutionary-ecological perspective. Sinauer Associates, Sunderland, Massachusetts, USA.

Soule, M.E., editor. 1987. Viable populations for conservation. Cambridge University Press, Cambridge, UK.

Soule, M.E., J.A. Estes, J. Berger, and C. Martinez del Rio. 2003. Ecological effectiveness: conservation goals for interactive species. Conservation Biology 17(5):1238-1250.

Soule, M.E., J.A. Estes, B. Miller, D.L. Honnold. 2005. Strongly interacting species: conservation policy, management, and ethics. BioScience 55(2):168-176.

Soule, M.E., and D. Simberloff. 1986. What do genetics and ecology tell us about the design of nature reserves? Biological Conservation 35:19-40.

Soule, M.E., and B.A. Wilcox, editors. 1980. Conservation biology: an evolutionary-ecological perspective. Sinauer Associates, Sunderland, Massachusetts, USA.

Terborgh, J., J.A. Estes, P.C. Paquet, K. Ralls, D. Boyd-Heger, B. Miller, R. Noss. 1999. Role of top carnivores in regulating terrestrial ecosystems. Pages 39-64 *in* Soule, M.E., and J. Terborgh, editors. Continental conservation: design and management principles for long-term, regional conservation networks. Island Press, Washington, D.C.

Thiel, R.P. 1985. Relationship between road densities and wolf habitat suitability in Wisconsin. American Midland Naturalist 113(2):404-407.

Thomas, C.D. 1990. What do real population dynamics tell us about minimum viable poulation sizes? Conservation Biology 4:324-327.

U.S. Fish and Wildlife Service [USFWS]. 1982. Mexican wolf recovery plan. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 1987. Northern Rocky Mountain wolf recovery plan. Region 6, Denver, Colorado, USA.

U.S. Fish and Wildlife Service [USFWS]. 1992. Recovery plan for the eastern timber wolf. Region 3, Twin Cities, Minnesota, USA.

U.S. Fish and Wildlife Service [USFWS]. 1993. Comparison of habitat suitability attributes of five areas being considered for the reintroduction of Mexican wolves. Unpublished report, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 1994. Appendix 9: Memorandum regarding a viable wolf population in the Northern Rocky Mountains. *In* The reintroduction of gray wolves to Yellowstone National Park and Central Idaho. Region 6, Helena, Montana, USA. http://www.fws.gov/mountain-prairie/species/mammals/wolf/EIS_1994.pdf

U.S. Fish and Wildlife Service [USFWS]. 1996. Reintroduction of the Mexican wolf within its historic range in the southwestern United States: Final Environmental Impact Statement. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 2002. Environmental Assessment for the translocation of Mexican wolves throughout the Blue Range Wolf Recovery Area in Arizona and New Mexico. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 2001. Mexican wolf recovery program: Mexican wolf reintroduction progress report 4. Technical Report. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 2002a. Draft wolf population viability peer review. Draft summary prepared by Ed Bangs, Wolf Recovery Coordinator. Region 6, Helena, Montana, USA.

U.S. Fish and Wildlife Service [USFWS]. 2002b. Mexican wolf recovery program: Mexican wolf reintroduction progress report 5. Technical Report. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 2003. Mexican wolf recovery program: Mexican wolf reintroduction progress report 6. Technical Report. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 2004. Mexican wolf recovery program: Mexican wolf reintroduction progress report 7. Technical Report. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 2005. Mexican wolf recovery program: Mexican wolf reintroduction progress report 8. Technical Report. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 2006a. Mexican wolf recovery program: Mexican wolf reintroduction progress report 9. Technical Report. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 2006b. Letter from Acting Regional Director Benjamin Tuggle, Southwest Region, USFWS, to Terry B. Johnson, Chair, Adaptive Management Oversight Committee, regarding 5-Year Review. Signed July 24, 2006.

U.S. Fish and Wildlife Service [USFWS]. 2008. Mexican gray wolf recovery program website. <http://www.fws.gov/southwest/es/mexicanwolf/>. Accessed March 1 – August 29, 2008.

U.S. Fish and Widlife Service [USFWS]. 2008a. Region 6 homepage. <http://www.fws.gov/mountain-prairie/pressrel/08-16.htm>. Accessed March 9, 2008.

U.S. Fish and Wildlife Service [USFWS], Nez Perce Tribe, National Park Service, Montana Fish, Wildlife and Parks, Blackfeet Nation, Confederated Salish and Kootenai Tribes, Idaho Fish and Game, and U.S. Department of Agriculture Wildlife Services. 2008. Rocky Mountain wolf recovery 2007 annual report. Sime, C.A., and E. E. Bangs, editors. U.S. Fish and Wildlife Service, Region 6, Helena, Montana, USA.

Unsworth, R., L. Genova, K. Wallace, A. Harp. 2005. Mexican wolf Blue Range reintroduction project 5-year review: socioeconomic component. Final Report. Prepared for Division of Economics, U.S. Fish and Wildlife Service, Arlington, Virginia, USA. http://www.fws.gov/southwest/es/mexicanwolf/pdf/MW5YRSocioeconomicsFinal20051231.pdf

Vilá, C., I.R. Amorim, J.A. Leonard, D. Posada, J. Castroviejo, F. Petrucci-Fonseca, K.A. Crandall, H. Ellegren, and R.K. Wayne. 1999. Mitochondrial DNA phylogeography and population history of the grey wolf, *Canis lupus*. Molecular Ecology 8:2089-2103.

Vucetich, J.A., M.P. Nelson, M.K. Phillips. 2006. The normative dimension and legal meaning of endangered and recovery in the U.S. Endangered Species Act. Conservation Biology 20:1383-1390.

Vucetich, J.A., R.O. Peterson, and T.A. Waite. 1997. Effects of social structure and prey dynamics on extinction risk in gray wolves. Conservation Biology 11:957-965.

Wabakken, P, H. Sand, I. Kojola, B. Zimmermann, J. M. Arnemo, H. C. Pedersen, and O. Liberg. 2007. Multistage, long-range natal dispersal by a global positioning system-collared Scandinavian wolf. Journal of Wildlife Management 71:1631-1634.

Waples, R.S. 2002. Definition and estimation of effective population size in the conservation of endangered species. Pages147-168 *in* Beissinger, S.R., and D.R. McCoullough, editors. Population viability analysis. University of Chicago Press, Chicago, Illinois, USA.

Waples, R.S., P.B. Adams, J. Bohnsack, and B.L. Taylor. 2007. A biological framework for evaluating whether a species is threatened or endangered in a significant portion of its range. Conservation Biology 21(4):964-974.

Wayne, R.K., E. Geffen, and C. Vilá. 2004. Population and conservation genetics of canids. Pages 55-84 *in* MacDonald, D.W., and C. Sillero-Zubiri, editors. Biology and conservation of wild canids. University Press, Oxford, UK.

Wayne, R.K., N. Lehman, M.W. Allard, R.L. Honeycutt. 1992. Mitochondrial DNA variability of the gray wolf: genetic consequences of population decline and habitat fragmentation. Conservation Biology 6(4):165-175.

Wayne, R.K., N. Lehman, and T.K. Fuller. 1995. Conservation genetics of the gray wolf. Pages 55-84 *in* Carbyn, L.N., S.H. Fritts, and D.R. Seip. Ecology and conservation of wolves in a changing world. Occasional Publication No. 35. Canadian Circumpolar Institute, University of Alberta, Edmonton, Alberta, Canada.

Wayne, R.K., N. Lehman, D. Gorman, D.A. Gilbert, K. Hansen, R.O. Peterson, U.S. Seal, A. Eisenhawer, L.D. Mech, and J. Krumenaker. 1991. Conservation genetics of the endangered Isle Royale gray wolf. Conservation Biology 5:41-51.

Wayne, R.K., and C. Vilá. 2003. Molecular genetic studies of wolves. Pages 218-238 *in* Mech, L.D., and L. Boitani, editors. Wolves: behavior, ecology, and conservation. The University of Chicago Press, Chicago, Illinois, USA.

Weaver JL, PC Paquet, and LF Ruggiero. 1996. Resilience and conservation of large carnivores in the Rocky Mountains. Conservation Biology 10: 964-976.

Wilson, P.J., S. Grewal, T. McFadden, R.C. Chambers, and B.N. White. 2003. Mitochondrial DNA extracted from eastern North American wolves killed in the 1800s is not of gray wolf origin. Canadian Journal of Zoology 81:936-940.

Young, S.P., and E.A. Goldman. 1944. The Wolves of North America. The American Wildlife Institute, Washington, D.C., USA.

Zarnke, R.L., J. Evermann, J.M. Ver Hoef, M.E. McNay, R.D. Boertje, C.L. Gardner, L.G. Adams, B.W. Dale, J. Burch. 2001. Serological survey for canine coronavirus in wolves from Alaska. Journal of Wildlife Diseases 34(4):740-745.

APPENDIX A: FIGURES

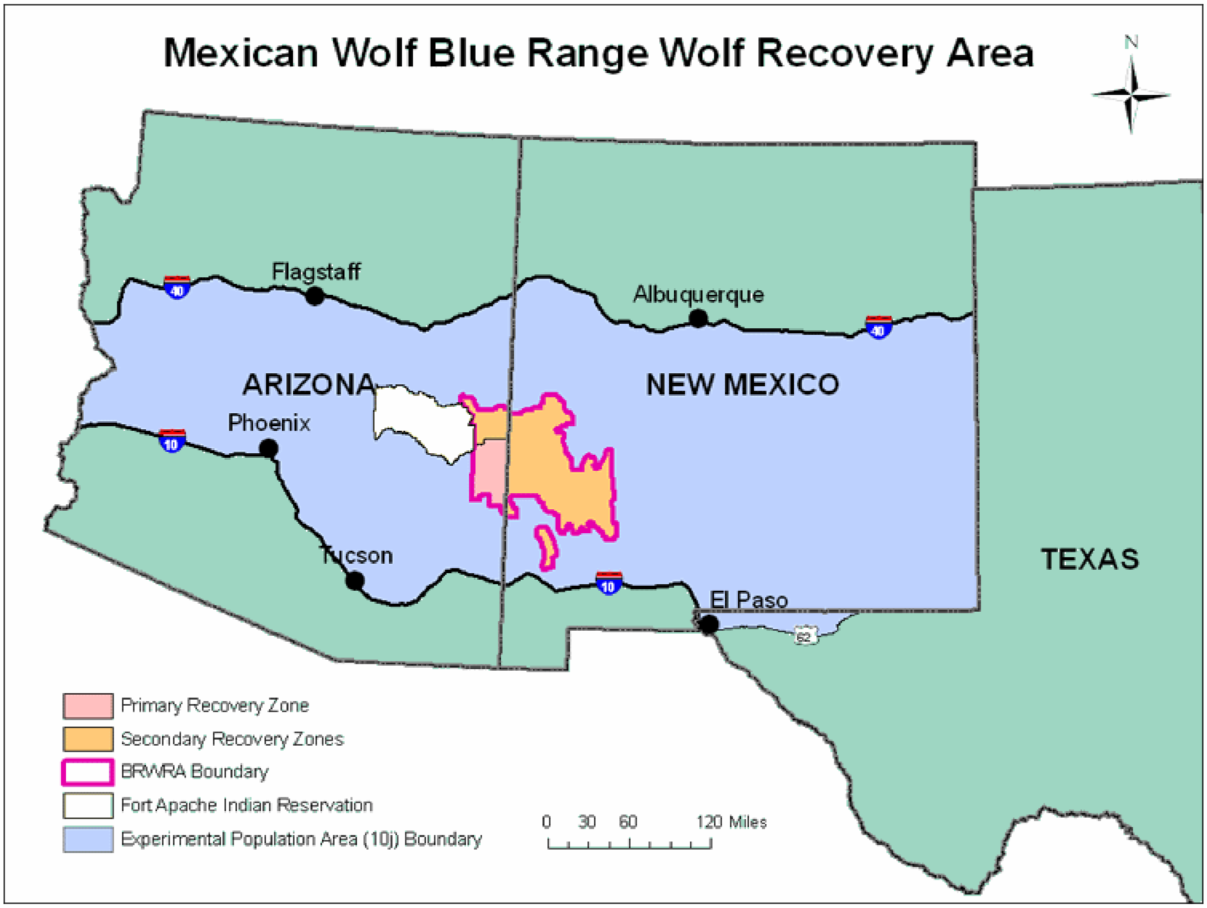

Figure 1: Mexican Wolf Blue Range Wolf Recovery Area. USFWS.


Figure 2. Photo of Mexican wolf. USFWS.