PREFACE

(Note to Reviewer: The below paragraph is mandatory language that must be included somewhere in the introductory sections of a recovery plan; anything else in this section is optional. Let’s wait until we’ve got more of the plan put together to determine whether we need anything else.)

The purpose of a recovery plan is to provide a scientifically based, logical, and effective roadmap for the recovery of a species. It explains what is needed for species recovery and how to get there. Recovery plans are advisory documents, not regulatory documents. A recovery plan does not commit any entity to implement the recommended strategies or actions contained within it for a particular species, but rather provides guidance for ameliorating threats and implementing proactive conservation measures, as well as providing context for implementation of other sections of the ESA, such as section 7(a)(2) consultations on Federal agency activities, development of Habitat Conservation Plans, or the creation of experimental populations under section 10(j).
DISCLAIMER
(Note to Reviewer: The text in this section is standard, required “legalese” language in all recovery plans so please do not provide edits.)

Recovery plans delineate reasonable actions believed to be required to recover and/or protect listed species. Plans published by the U.S. Fish and Wildlife Service (FWS), are sometimes prepared with the assistance of recovery teams, contractors, state agencies, and other affected and interested parties. Recovery teams serve as independent advisors to FWS. Plans are reviewed by the public and submitted to additional peer review before they are adopted by FWS. Objectives of the plan will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific tasks and may not represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than FWS. They represent the official position of FWS only after they have been signed by the Regional Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

By approving this document, the Regional Director will certify that the data used in its development represent the best scientific and commercial data available at the time it was written. Copies of all documents reviewed in development of the plan are available in the administrative record located at New Mexico Ecological Services Field Office, U.S. Fish and Wildlife Service, 2105 Osuna Dr., NE, Albuquerque, NM, 87113, #505-346-2525 or 1-800-299-0196.
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(continue list as needed, Colby Gardner/Kevin Winters/GIS, etc?)

The writing of the plan took place in several stages. Much of the background material was modified extensively by members of the Science and Planning Subgroup from the 2010 Mexican Wolf Conservation Assessment through team review and updated field data and information. The Recovery Strategy and Recovery Criteria subsections were written by members of the Science and Planning Subgroup. The Tribal Perspectives chapter was written by members of the Tribal Subgroup and the Agency Subgroup. The…. (i.e., explain how the plan was written, that there was not necessarily “consensus” throughout, name individual contributors if desired, etc).
LITERATURE CITATION AND AVAILABILITY

Literature citation should read as follows:

Copies of the document can be requested from:

U.S. Fish and Wildlife Service
New Mexico Ecological Services Field Office
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Copies are also available on-line at:
http://www.fws.gov/southwest/es/mexicanwolf
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EXECUTIVE SUMMARY

(Note to Reviewer: We will write this section last.)
I. BACKGROUND

A. Brief Overview

(Note to Reviewer: This section should orient the reader to the situation.)

Recovery Planning

The Mexican Wolf Revised Recovery Plan (Plan) is the first recovery plan developed for the Mexican wolf that contains the required recovery plan elements specified by the Endangered Species Act (ESA, or Act) (section 4(f)(1)):

i) a description of such site-specific management actions as may be necessary to achieve the plan’s goal for the conservation and survival of the species;

ii) objective, measurable criteria which, when met, would result in a determination, in accordance with the provisions of this section, that the species be removed from the list; and

iii) estimates of the time required and the cost to carry out those measures needed to achieve the plan’s goal and to achieve intermediate steps toward that goal.

Two other recovery plans have been written for the Mexican wolf: the 1982 Mexican Wolf Recovery Plan, which was written by a recovery team established by the Service and signed by the Service and the Dirección General de la Fauna Silvestre in Mexico; and the Programa de Recuperación del Lobo Mexicano (Programa de Recuperacion), written by a team of scientists in Mexico, in 1999 (SEMARNAP 2000). Both of these plans acknowledge the binational historical range of the Mexican wolf within the United States and Mexico, but each plan was written within the context of the federal laws governing its content: the 1982 Mexican Wolf Recovery Plan was written pursuant to the Service’s obligation to develop recovery plans for species protected by the Act, whereas Mexico’s plan was written pursuant to the Mexican federal law protecting wildlife, Norma Oficial Mexicana NOM-059-ECOL-1994.

The 1982 Mexican Wolf Recovery Plan did not contain all three of the recovery plan elements specified in section 4(f)(1) of the Act. 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. Therefore, they stopped short of providing the objective and measurable recovery criteria required by the Act. Instead, the recovery team laid out a “prime objective”:

“To conserve and ensure the 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).”

The recovery actions and attending time and cost estimates in the 1982 Recovery Plan focused on information gathering and management recommendations in support of this prime objective. The Service initiated revision to the 1982 Mexican Wolf Recovery Plan in the mid-1990s and early 2000’s. These revisions were not finalized due to logistical issues, including litigation related to gray wolf reclassifications (see National Gray Wolf Recovery, below).

Mexico’s Programa Recuperacion was not required by law to set a numeric goal for recovery. It did, however, establish an objective to reach population levels that would ensure long-term viability by reintroducing Mexican wolves into several areas in Mexico (V: Objectives, VI: Strategies, Projects, and Actions) (SEMARNAP 2000). The document explained that Mexico supported reintroduction on both sides of the Mexico-United States border, and stated that it would be difficult to find appropriate habitat for reintroduction in Mexico. The plan suggested that the best habitat may exist within the Sierra Madre Occidental and the Sierra Madre Oriental mountain ranges (SEMARNAP 2000).

The 201x Mexican Wolf Revised Recovery Plan replaces and supersedes the Service’s 1982 Mexican Wolf Recovery Plan, but it does not replace, supersede, or otherwise affect Mexico’s Programa de Recuperacion. [More here as necessary to broadly describe national/bi-national aspects of this plan.]

Recovery Implementation in the United States and Mexico

Recovery efforts for the Mexican wolf have been underway in the United States and Mexico for several decades. Both countries have adopted a two-pronged approach to recovery: maintaining a captive population of Mexican wolves, and re-establishing wild populations by releasing captive wolves into designated reintroduction areas.
The Mexican wolf captive breeding program established in the late 1970’s saved the Mexican wolf from extinction. The breeding program was founded by three of the last six Mexican wolves removed from the wild in Mexico. The first Mexican wolf pups were conceived and born in captivity in the United States in 1981 (Parsons 1996, Hedrick et al. 1997, Lindsey and Siminski 2007). Mexico formally joined the captive breeding effort in 1987 (SEMARNAP 2000), and by 1994, the binational breeding program had produced a captive population of 92 wolves. These founding wolves and their offspring were initially referred to as the Certified lineage, later renamed the McBride lineage. In 1995, 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 due to the limited genetic diversity of the captive population and the potential for inbreeding depression to hinder its success (Parsons 1996, Hedrick et al. 1997). This increased the founding base of the captive population from three to seven pure Mexican wolves (Hedrick et al. 1997).

Today, the binational captive breeding program continues to conserve the subspecies’ genome and provide healthy offspring for release to the wild (Parsons 1996, Lindsey and Siminski 2007). The program has been managed pursuant to breeding protocols and genetic and demographic goals established by the Association of Zoos and Aquariums’ Species Survival Plan (AZA Mexican Wolf SSP) since 1994 (Siminski and Spevak 2011). The captive breeding program currently houses 283 wolves in 52 facilities, 34 of which are in the United States and 18 of which are in Mexico (Siminski and Spevak 2011). In an analysis of the captive population in 2011, the calculated retention of the original gene diversity of the founding seven wolves was 83.3 percent (Siminski and Spevak 2011). However, it is anticipated that even with optimal managment, the genetic diversity in the captive population will continue to decline.

The United States and Mexico have both initiated re-establishment of the Mexican wolf in the wild by releasing captive-bred wolves into areas of suitable habitat in each country. In the United States, Mexican wolves were reintroduced to the wild in 1998 (cite annual report); as of December 31, 2011, a population of approximately 58 wild Mexican wolves inhabits the
southwestern United States (update, cite). Mexico reintroduced Mexican wolves to the wild in 2011; as of MONTH, 2012 x wild Mexican wolves inhabit Mexico (update, cite). These reintroduction efforts are independent of the captive breeding program, although closely coordinated. The United States and Mexico also communicate their reintroduction plans with one another, share equipment, and transfer information and technology through staff visits to each country. Implementation of reintroductions occurs according to the legal frameworks and management provisions relevant to each country.

In the United States, plans for the reintroduction of the Mexican wolf to the wild began to develop in the early-1990s, stimulated in part by a suit filed against the 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. 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 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 Final Rule established the Mexican Wolf Experimental Population Area (MWEPA) in central Arizona and New Mexico, and designated the reintroduced population as a non-essential experimental population under section 10(j) of the ESA (Figure x). This designation was justified because wolves released to the wild would be genetically redundant to 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 gaining public support (63 FR 1752-1772, January 12, 1998; Brown
and Parsons 2001). The rule stipulated that the reintroduction of wolves would take place within
the Blue Range Wolf Recovery Area, a 17,775 km (6,845 mi) area within the MWEPA that
included the Apache National Forest in east-central Arizona and the Gila National Forest in
west-central New Mexico. The remainder of the MWEPA outside of the BRWRA was
considered reintroduction and recovery habitat for the Mexican wolf; rather it provided a
transition zone between the BRWRA 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 strategy for the reintroduction was to release 14 family groups of wolves into the Blue
Range Wolf Recovery Area over a period of five 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 and 18 breeding pairs would be reached in 2006 (USFWS 1996). Because a source
population of Mexican wolves did not exist in the wild, the reintroduction would be initially
dependent on captive-bred wolves. As of December 31, 2011, the minimum estimate for the
BRWRA population is 58 wolves, about half of the minimum population objective (USFWS
2011).

In 2000, WMAT agreed to allow wolves to inhabit Fort Apache Indian Reservation, and in 2002
signed an agreement allowing direct release of wolves onto FAIR, providing an additional 500
mi (6,475 km) of wolf habitat.

In October 2011, Mexico released five captive wolves to the wild in Sonora (cite). Four of these
wolves were illegally (and fatally) poisoned within several months of release. Mexico plans on
releasing additional wolves in this area, and in other areas targeted for reintroduction, in the near
future. Since Mexico developed its Programa de Recuperacion, researchers in Mexico have
conducted several habitat analyses to identify areas of suitable habitat for the establishment of
wild wolf populations (see Section I.H. and Modeling Appendix Section 5.B.).

With the recent release of wolves in Mexico close to the United States-Mexico border, there is
potential for wolves from Mexico to disperse into the United States. Based on the current Code
of Federal Regulations (cite), such wolves would be considered “endangered” anywhere in the
Southwest other than within the boundaries of the Mexican wolf non-essential experimental
population (see Figure x). Wolves entering into this zone from Mexico will be managed
pursuant to a management plan developed by the Service, in coordination with the states of
Arizona, New Mexico, and Texas, and Mexico (cite).

National Gray Wolf Recovery
Since the Service’s listing of the gray wolf in the coterminous United States in 1978 (43 FR
9607-9615, March 9, 1978), the Service has implemented three gray wolf recovery programs in
different regions of the country: the Western Great Lakes (Minnesota, Michigan, and Wisconsin,
administered by the Service’s Great Lakes, Big Rivers Region), the Northern Rocky Mountains
(Idaho, Montana, and Wyoming, administered by the Service’s Mountain-Prairie Region and
Pacific Region), and the Southwest (Arizona, New Mexico, Texas, Oklahoma, Mexico,
administered by the Service’s Southwest Region). Recovery plans were developed in each of
these areas to organize and prioritize recovery criteria and actions appropriate to the unique local
circumstances of the gray wolf. As such, the three gray wolf recovery programs have functioned
independently from one another since their inceptions. The Service also initiated a red wolf
(Canis rufus) recovery program in 1982 in the eastern United States that it continues to
implement today.

Progress toward recovery of gray wolves in the Western Great Lakes, Northern Rocky
Mountains, and Southwest has differed substantially between the regions over the last four
decades.
B. Status of the Species

(Note to Reviewer: This section should provide the species’ federal and state status, and FWS recovery priority status; the rest of the section should note things of importance related to species status.)

The gray wolf, *Canis lupus*, is currently listed as endangered with a recovery priority number of (X) (cite 1978 FR or update with reclassification if applicable). The Service originally listed the Mexican wolf subspecies in 1976 (41 FR 17736-17740, April 28, 1976). In 1978, this and several other gray wolf subspecies-level listings were subsumed into a species-level listing to protect the gray wolf 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. The Service’s Mexican wolf program is conducted as a component of the agency’s gray wolf recovery obligations under the ESA.

In addition to its listed status under the ESA, the gray wolf is also protected under State wildlife statutes in the Southwest. The gray wolf is managed as a species of Special Concern and is identified as a Species of Greatest Conservation Need (endangered) in Arizona (Wildlife of Special Concern in Arizona 1996), and listed as state 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 a 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). The gray wolf is not listed or protected by State law in Oklahoma.

C. Description

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*), Eastern wolf (*Canis lycaon*), dog (*C. familiaris*), coyote (*C. latrans*), several species of jackal (*C. aureus, C. mesomelas, C. adustus*) and the dingo (*C. dingo*) (Mech 1970, Chambers et al. 20xx). The Mexican wolf, *C. l. baileyi*, is a subspecies of gray wolf (Nelson and Goldman 1929). Type localities of previously recognized subspecies are documented in Young and Goldman (1944). The type locality of *Canis lupus baileyi* is Colonia Garcia, Chihuahua, Mexico based on a gray wolf was killed during a biological investigation in the mountains of Chihuahua, Mexico in 1899. Thirty years later this animal was combined with additional specimens to define the Mexican wolf (*Canis lupus baileyi*) (Nelson and Goldman 1929).

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. Females are typically 15-20 percent smaller than males in weight and length (Mech 1970). The Mexican wolf 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). 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). 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).
D. Taxonomy and Distribution

Taxonomy

It is likely that 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 modern gray wolf, with the possible exception of the wolves of southeastern Canada and northeastern United States (Wilson et al. 2003), likely evolved in Eurasia from wolves that crossed into Eurasia from North America. A branch of these wolves (that is, *Canis lupus*) then reinvaded North America during the middle Pleistocene (around 300,000 years ago) via the Bering Strait land bridge (Wayne et al. 1992, Brewster and Fritts 1995, Nowak 1995, Parsons 1996, Nowak 2003: Table 9.2). It is hypothesized that there were at least three waves of colonization from Eurasia each from different wolf lineages in response to changing glacial ice patterns and openings in the Bering Sea (Nowak 1995, Nowak 2003, Wayne and Vilà 2003). The Mexican wolf may represent the last surviving remnant of the initial wave of gray wolf migration (vonHoldt et al. 2011). Once in North America, wolves dispersed southward and eastward, gradually spreading across much of the continent (Parsons 1996, Nowak 2003).

*C. l. baileyi* has been recognized as a subspecies of gray wolf since its description by Nelson and Goldman (1929; Goldman 1937). Goldman (1944, pp. 389-636), provided the first comprehensive treatment of North American wolves; this gray wolf classification scheme was subsequently followed by Hall and Kelson (1959, Hall 1981). Since that time, gray wolf taxonomy has undergone substantial revision, including a major taxonomic revision in which the number of recognized gray wolf subspecies was reduced from 24 to 5 (Nowak 1995). However, the distinctiveness of *C. l. baileyi* and its recognition as a subspecies continues to be supported by both morphometric and genetic evidence.

Three published studies of morphometric variation conclude that *C. l. baileyi* is a morphologically distinct and valid subspecies. Bogan and Mehlhop (1983) analyzed 253 gray wolf skulls from southwestern North America using principal components analysis and discriminant function analysis. They found that *C. l. baileyi* was one of the most distinct of the
five subspecies of gray wolves in the Southwest recognized at that time. Hoffmeister (1986) conducted principal component analysis of 28 skulls, also recognizing C. l. baileyi as a distinct southwestern subspecies. Nowak (1995) analyzed 580 skulls from across North America using discriminant function analysis. He concluded that C. l. baileyi was one of only five distinct North American gray wolf subspecies that should continue to be recognized.

Genetic research provides additional validation of the recognition of C. l. baileyi as a subspecies. Three studies demonstrate that Mexican wolves have unique genetic markers that distinguish them from other North American gray wolves. Hedrick et al. (1997; see also Garcia-Moreno et al. 1996; Wayne 19995) examined data for 20 microsatellite loci, from samples of Mexican wolves (N=38), northern gray wolves (N=55), coyotes (N=39), and dogs (N=27). They concluded that Mexican wolves were divergent and distinct from other sampled northern gray wolves, coyotes and dogs. They also determined that data from two captive groups of putative Mexican wolves were consistent with the conclusion that these animals were in fact Mexican wolves, and that these groups should be interbred with the captive certified lineage of Mexican wolves (now known as the McBride lineage) that had founded the captive breeding program. Leonard et al. (2005) examined mitochondrial DNA sequence data from 34 pre-extinction wolves collected from 1856 to 1916 from the historic ranges of C. l. baileyi and C.l. nubilus. They compared these data with sequence data collected from 96 wolves in North America and 303 wolves from Eurasia. They found that the historic wolves had the twice the diversity of modern wolves, and that two-thirds of the haplotypes were unique. They also found that haplotypes associated with Mexican wolves formed a unique southern clade distinct from that of other North American wolves. A clade is a taxonomic group that includes all individuals (in this case DNA haplotypes) that have descended from a common ancestor. VonHoldt et al. 2011 investigated the taxonomy of wolves and coyotes world-wide using 48,000 single nucleotide polymorphisms (SNPs) and found Mexican wolves to be the most genetically distinct group of New World gray wolves, again supporting the validity of the subspecies.

Most recently, Chambers et al. (2012, in review) reviewed the scientific literature related to C. l. baileyi’s classification as a subspecies and concluded that this subspecies’ recognition remains well-supported.
Distribution

Gray wolves were once abundant and widespread in North America. Before European settlement, the gray wolf ranged from the Canadian high arctic through the United States to central Mexico (Mech 1970, Wayne and Vilá 2003), with the exception of the southeastern United States which was occupied by the red wolf (U.S. Fish and Wildlife Service 1989). Although recognition of the Mexican wolf as a subspecies is well supported, differing interpretations of gray wolf taxonomy and distribution have resulted in multiple descriptions of Mexican wolf historical range in the southwestern United States and Mexico.

Based on morphology (mostly skull and pelage characteristics) 24 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*. Original descriptions of Mexican wolf range by Young and Goldman (1944) and Hall and Kelson (1959) delineated range for each of *C. l. baileyi*, *C. l. monstrabilis*, and *C. l. mogollonensis* (Figure ). Hall (1981) described the range of *C. l. baileyi* as including only a small portion of extreme southwestern New Mexico and southeastern Arizona. Bogan and Mehlhop (1980, 1983) combined *C. l. mogollonensis* and *C. l. monstrabilis* with *C. l. baileyi*, thereby extending *C. l. baileyi*’s range to central Arizona and central New Mexico (Figure ). 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 contrast to Bogan and Mehlhop (1980, 1983), Hoffmeister (1986) regarded *C. l. mogollonensis* as a synonym of *C. l. youngi*.

Brown (1983) stated that 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 in the late 19th and early 20th centuries. In central Arizona, he described a mixing ground where Mexican wolves and several formerly recognized subspecies of gray wolf were interspersed (Brown 1983). He also stated that 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). Brown (1983) described Mexican wolves frequenting the borderlands between Mexico and the US, and claimed that they were abundant in the Sierra Madre and the altiplano (high plains) of Mexico.

In 1995, Nowak proposed a major shift from the identification of 24 subspecies of North American gray wolves to only 5 subspecies (1995), recognizing *C. l. baileyi* as a subspecies, but grouping *C. l. mogollonensis* and *C. l. monstrabilis* with *C. l. nubilus*, providing a more restrictive range for *C. l. baileyi* than Bogan and Mehlhop (Figure ). It is important to note that Nowak (1995) agreed with Bogan and Mehlhop (1983) that the range of *C. l. mogollonensis* in Arizona was a transition zone where *C. l. baileyi* intergraded with more northern *C. lupus*. 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 (Figure ). The Service adopted the historical range proposed by Parsons (1996) for *C. l. baileyi*, which represented a 200-mile northward extension of Nowak’s (1995) range for *C. l. baileyi*, and included it in the FEIS (USFWS 1996). In an exhaustive review of molecular genetics and morphological data, Chambers et al (2012, in review) recommended that the historical range for *C. l. baileyi* be extended northward from that proposed by Nowak (1995) (Figure 8).

Evidence of historical gene flow across the various surmised boundaries of *C. l. baileyi* suggests that Mexican wolves likely intergraded with other gray wolves in a wide zone at the northern extent of their range. Wolves’ dispersal behavior as revealed by numerous telemetric studies (Mech and Biotani 2003) has long led to the contemporary conclusion that there were large zones of intergradation across the North American landscape (Young and Goldman 1944, Mech 1970, Brewster and Fritts 1995) and suggests that the periphery of Mexican wolf historical range occurred somewhere within such a zone. Analyses of historic specimens (Leonard et al. 2004) demonstrate that the gray wolves that inhabited northern Arizona, Utah, northern New Mexico, and southern and central Colorado had genetic markers associated with the Mexican wolf. This
research shows that within the time period that the historic specimens were collected (1856-
1916) a mitochondrial DNA haplotype characteristic of northern wolves was found as far south
as Arizona, and individuals with southern clade haplotypes (associated with the Mexican wolf)
occurred as far north as northern Utah and Nebraska (Leonard et al. 2005).

There is some indication that wolf distribution shifted subsequent to widespread eradication
efforts in 1900’s (see Historical Population Trends), as wolves from one area were able to
occupy recently vacated habitat. Scudday (1977) reported on two male Mexican wolves
collected in 1970 in Brewster County, Texas and concluded that C. l. baileyi “was a late comer to
Texas, probably moving in as C. l. monstrabilis was eliminated in the Trans-Pecos region.” Gish
(1977) thought that C. l. baileyi increasingly moved into Arizona from Mexico and southwestern
New Mexico as other subspecies were eliminated in Arizona. Nowak (1995) noted that a male
Mexican wolf taken in 1957 near Concho, Arizona, was well within the original range of C. l.
mogollonensis. By 2002, Nowak (personal communication with Mike Phillips) had concluded
that the two animals collected from Brewster County, Texas and the one animal collected near
Concho, Arizona represented a 160 km northward extension of the historical range that he had
recommended for the subspecies in 1995.
E. Historical Population Trends

Population estimates of gray wolves, and specifically Mexican wolves, prior to the advent of extermination efforts 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 in some part to difficulty in interpreting anecdotal accounts of wolf abundance. Brown (1983) summarized historical distribution records for the wolf from McBride (1980) and other sources that repeatedly indicated, at least for the southwestern United States, that wolves were common. His map (Brown 1983: 10) shows most records in the southwestern United States as being from the Blue Range and the Animas region of New Mexico. The high number of wolf bounties collected in southern Colorado and northern New Mexico suggest that wolves were abundance in that area as well (Robinson 2005). Wolves appear to have been less numerous in northern Arizona during this time period, with only 30 wolves reported killed on or near the North Kaibab between 1907 and 1926 (Russo 1964). Young and Goldman (1944) stated that in 1916-8 the wolf was fairly numerous in Sonora, Chihuahua, and Coahuila. Brown (1983) described the Sierra Madre Occidental in the Mexican states of Sonora, Chihuahua, and Durango as a stronghold for the Mexican wolf. Leonard et al. (2005) analyzed mitochondrial DNA sequences of 34 pre-extirmination wolves and found that they had more than twice the diversity of their modern conspecifics, implying a historic population of several hundred thousand wolves in the western U.S. and Mexico.

The status of the Mexican wolf declined rapidly to near extinction during the 1900’s. The intensification of human settlement, agriculture, and livestock operations in the Southwest in the 1800’s led to human persecution of wolves due to wolf depredation of livestock (Brown 1983, Robinson 20xx?). Federal control programs and extermination campaigns, coupled with habitat alteration resulting from settlement patterns, 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, although occasional reports of wolves crossing into the United States from Mexico persisted into the 1960s. By the time of Leopold (1959), the formerly continuous wolf distribution in northern Mexico had contracted to encompass the Sierra Madre Occidental in Chihuahua, Sonora, and Durango, as well as a disjunct population in western Coahuila (from the Sierra del Carmen westward). Leopold (1959) found conflicting reports on the status of the Coahuila population and stated that wolves were likely less abundant there than in the Sierra Madre Occidental. McBride (1980) surveyed the distribution of the last wild populations of Mexican wolves. He mapped three general areas where wolves were recorded as still present in the Sierra Madre Occidental: 1) northern Chihuahua/Sonora border (at least eight wolves); 2) western Durango (at least 20 wolves in two areas); and 3) a small area in southern Zacatecas. McBride (1980) believed that wolves did not occur in northern and eastern Coahuila despite the existence of what he judged to be excellent wolf habitat there. Although occasional anecdotal reports have been made during the last three decades that a few wild wolves still inhabit forested areas in Mexico, no publicly available documented verification exists.
F. Current Population Trends and Distribution

(Note to Reviewer: The text below has been adapted from the CA. Entire section needs to be updated through 2012 annual reports as available. Needs graphs/visuals.)

United States

The population trends and distribution of the current wild nonessential experimental Mexican wolf population in the BRWRA are well documented, as monitoring of the population has been ongoing since its inception in 1998. Between one and 21 wolves have been released into the the BRWRA every year since 1998, with the exception of 2005, 2007, 2009, 2010 (update with 2011-2012) in which no wolves were released (cite online stats or 2011 annual report). As of December 31, 2012, the Blue Range population consisted of a minimum of xx wolves and xx breeding pairs (cite end of year count/annual report). The growth of the population from its initial end-of-year count of four wolves in 1998 to a minimum of xx wolves today is attributed to continued releases and to natural reproduction (AMOC and IFT: TC-11).

The growth of the Blue Range population has been more modest than expected based on the agency’s initial predictions (cite FEIS). Between 1998 and 2003, the Blue Range population tracked fairly closely to FEIS projections for population count, reaching (a minimum of) 55 wolves in 2003, but was consistently below the FEIS’s estimated number of breeding pairs. The population decreased significantly in 2004-2005 and then rebounded to a high of 59 wolves in 2006, the year in which the FEIS projected the population target of 100 would be met. Between 2007-2011, the population has fluctuated between a minimum count of 42-xx wolves and two (2011?) to four breeding pairs. Thus, the population has remained around the halfway point of the population target since 2003, with fewer breeding pairs than estimated (cite USFWS: Mexican Wolf Blue Range Reintroduction Project Statistics or 2011 annual report) (Figure/s).

BRWRA Project Evaluation

Evaluation of the BRWRA reintroduction project has been on-going since its inception to identify biological and regulatory issues affecting its progress. Initial observation of the population from
1998-2000 documented that most of the captive-bred wolves that were released into the BRWRA were successfully establishing home ranges, breeding, and exploiting native prey, alleviating some apprehension over the use of inexperienced wolves (Brown and Parsons 2001). Challenges for the reintroduction, as seen after its first few years, included the intense management response necessary to address wolves dispersing outside of the BRWRA (which necessitated their removal due to the regulations established in the 1998 Final Rule), wolf-livestock interactions, the possible consequences of limited genetic diversity, and sociopolitical acceptance of the reintroduction (Brown and Parsons 2001), as evidenced by a very high level of illegal killing.

Two formal agency reviews of the reintroduction project were conducted at three and five years after its inception to determine whether the reintroduction should continue, or be modified or terminated, as stipulated in the Final Rule (63 FR 1752-1772, January 12, 1998). The technical component of the 3-Year Review, commonly referred to as the Paquet Report, assessed the progress of the reintroduction from its inception to 2001. The review was conducted by three independent researchers under contract to the Service: Paul Paquet, John Vucetich and Michael Phillips. Paquet et al. (2001) found that continuation of the population’s documented reproduction and survival rates would result in slower progress achieving the population target of at least 100 wolves than estimated during the planning of the reintroduction. They concluded that several factors were ultimately hindering the biological success of the project: 1) the small size of the Primary Recovery Zone of the BRWRA, which limited the establishment phase of the project by constraining the number and location of wolves that could be released; 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, Paquet et al. (2001) recommended the Service initiate a recovery team to revise the 1982 Mexican Wolf Recovery Plan, modify the Final Rule to allow initial releases into the Gila National Forest, and allow wolves to establish territories outside of the BRWRA.

The 5-Year Review evaluated the reintroduction from 1998 to 2003, but also included analysis of some aspects of the project through 2005. This review was conducted by the Mexican Wolf Adaptive Management Oversight Committee (AMOC) and the Interagency Field Team, the multi-agency group
leading the project and the multi-agency staff in charge of day to day operations, respectively. In the Technical Component of the Review, which addressed the biological progress of the project, AMOC concluded that at least until 2003, progress toward establishment of a population of at least 100 wolves had generally proceeded in line with projections from the FEIS. However, they also recognized that guidelines in the Final Rule requiring removal of wolves that establish home ranges outside of the BRWRA, or at landowner’s request, are contrary to normal wolf movements, 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 review recommended further analysis of potential modification of the Final Rule, 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 (AMOC and IFT: ARC). Following the completion of the 5-Year Review in 2005, the Service determined that the reintroduction should continue, and acknowledged that modifications to the Final Rule were necessary (USFWS 2006b).

The status of the reintroduction project is also documented and evaluated in annual Interagency Field team reports. Since the 5-Year Review, FWS and partner agencies have acknowledged in these reports that the population is lagging behind the projections of the FEIS, citing the high mortality and removal rates of the population as responsible for this trend (USFWS 2005:27) and concluding that changes in management are needed to support population growth (AGFD et al. 2007:13, AGFD et al. 2008). In 2010, the Service contracted with a former employee, Tracy Melbihess, to develop an assessment of the reintroduction project within the context of gray wolf recovery. The Mexican Wolf Conservation Assessment found that (…wild population faces a number of challenges; risk of extinction averted due to captive breeding program but wild population is susceptible to failure due to small size, lack of redundancy, cumulative effect of stressors/threats, etc.).
In October 2011, Mexico initiated the establishment of a wild Mexican wolf population in the Sierra San Luis Complex of northern Sonora and Chihuahua, Mexico. Officials released five captive-bred Mexican wolves into the San Luis Mountains in Sonora just south of the US-Mexico border (SEMARNAT e-press release, 2011). As of February 2012, four of the five released animals were confirmed dead due to ingestion of illegal poison (USFWS, our files). One wolf remains near the area in which it was released (USFWS, our files). Additional releases are tentatively planned for 2012-2013 to continue efforts to establish a wild population.
G. Life History

(Note to Reviewer: This section is copied directly from CA. Needs updating with 2009/2010/2011 annual reports.)

Basic descriptive life history information is well documented for gray wolves, although less so for the Mexican wolf since the subspecies had been extirpated before useful studies could be conducted. What we have learned in the recent past from captive breeding programs and the BRWRA project is that the Mexican wolf does not manifest any particularly unique life history strategies compared to other gray wolf subspecies.

In the wild, gray wolves typically live 4 to 5 years, although they can reach 13 years (Mech 1988). They reach sexual maturity at two 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 one pound (0.5 kg) at birth (Mech 1991), and remain inside the den for at least four 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).

Documentation in the BRWRA of wild-born wolves breeding and raising pups has been made for 11 years in a row (2001-2012), and in 2012 approximately x percent of wolves in the Blue Range population were wild-born (cite). In the wild, Mexican wolf pups are generally born between early April and early May (AMOC and IFT 2005: TC-6). Pup counts are conducted opportunistically after the denning period, but prior to October, at which point Mexican wolf pups are difficult to distinguish from adults (AMOC and IFT 2005: TC-6). Average litter size has been estimated at 3.26 (n = 95) pups in the reintroduced population (USFWFS files), which is noticeably smaller than Mexican wolf litters in captivity (4.6 pups/litter) (AMOC and IFT: TC-17-18), 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). Pup counts, however, are documented at some substantial time from whelping (post den emergence), thus some mortality would be expected prior to initial wild counts, and may explain the difference between the
number of pups counted in the wild and captivity. Note that red wolf litter sizes (2.8 pups/litter) during their initial restoration were similar (Phillips et al. 2003).

Recent analyses of the captive and reintroduced populations suggest the low litter sizes observed in the reintroduced population may be influenced by the level of inbreeding (Fredrickson et al. 2007). In the Blue Range population, the number of pups observed in packs producing cross-lineage pups (those descended from outbred F1 wolves created by the merging of the founding lineages) was 52 percent greater than packs producing pure McBride wolves, indicating that inbreeding may be negatively affecting litter sizes because fitness was greatest in the less-inbred cross-lineage wolves (Fredrickson et al. 2007). Several other factors may also explain small litter sizes in the reintroduced population due to early pup mortality: 1) wolves may be limited seasonally by the amount of vulnerable prey; 2) litter sizes may be an 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). Additionally, cryptic poaching of pups may be occurring before litters are censused (Liberg et al. 2012). Mexican wolf females from the wild population brought into captivity before or shortly after whelping pups had an average litter size matching that of the captive population (4.6 pups/litter, n = 6), suggesting that more Mexican wolf pups are born than are observed in the wild. Since litter size at birth and early pup mortality are unknown (AMOC and IFT 2005: TC-18), either could explain the small number of pups observed during pup counts.

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 and pup survival is typically highest in those areas of high prey availability (Fuller et al. 2003). Wolves are referred to as pups up to one year of age and yearlings when between one and two years of age (Packard 2003).

Pups begin hunting with adults when 4 to 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, scavenging carcasses, and have the ability to use a variety of prey and habitat types (Peterson and Ciucci 2003, Mech 1991, Weaver et al. 1996).

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 (Ballard et al. 2003, Fuller 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 December 31, 2011, illegal gunshot (43 of 88 deaths) and vehicle collision (14 of 68 deaths) were the two most prevalent causes of death (USFWS 2012: Population Statistics). Wolf population can compensate to a degree for relatively high mortality rates by means of increased reproduction, but current mortality rates in the Blue Range may exceed this level (Weaver et al. 1996, Oakleaf in prep., Vucetich et al. in review) The average annual survival rate of the Blue Range population between YEAR-YEAR is xx (or a corresponding failure rate of xx, which includes both mortality and management removal of wolves), a rate considered too low for natural population growth (cite).

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). The minimum number of breeding pairs observed in the Blue Range population is documented by the IFT in the annual end-of-year population count. “Breeding pair” as defined in the Final Rule as, “…an adult male and an adult female wolf that have produced at least two pups during the previous breeding season that survived until December 31 of the year of their birth” (50 CFR 17.84(k)(15). Over the span of the
reintroduction, the number of breeding pairs meeting the Final Rule definition has ranged from zero to seven pairs (USFWS 2012: Population Statistics). During two years, the Service interpreted the Final Rule to include any adult male and adult female associated with any two surviving pups at the end of the year, even if the adult pair did not breed (e.g., one member of a breeding pair is replaced by a new wolf that raises pups born to the former pair). This interpretation resulted in the number of breeding pairs counted being higher than if only the pairs that produced pups that survived until the end of the year were counted (AGFD et al. 2006, AGFD et al. 2007). Additional breeding events occur within the population, but do not meet the Final Rule definition for a breeding pair, making the original definition of “breeding pair” conservative. For example, in 2008, wild-born, wild-conceived pups were produced by seven packs (AGFD et al. 2008), but only XX of these packs had at least two surviving pups, and their biological parents, at the end of the year. Pack size in the Blue Range population between 1998 and 2012 ranged from 2 to x (mean = x) wolves ( ). Bednarz (1988) estimated historic Mexican wolf pack size as two to eight animals. Brown (1983) reported that Mexican wolf packs typically included fewer than 6 wolves. A wolf pack is typically some variation on a mated pair and offspring, sometimes of varying ages (Mech and Boitani 2003).

To secure food, water, and shelter, a pack establishes an area, or territory, that is maintained through scent-marking (Peters and Mech 1975), howling (Harrington and Mech 1983), and direct defense (Mech and Boitani 2003). 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).

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 trips to a
neighboring territory, or may be a long journey to find a mate and establish a territory. Dispersal
of more than 655 mi (1092 km) has been documented in northern populations (Wabakken et al.
movements) were documented in the Blue Range population, with an average distance of xx mi
+/- x mi (x km +/- x km). 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, x known mortalities were documented in association with
dispersal between 1998-2012 (including natural dispersal and movements directly after release to
the wild) (USFWS our files). Wolves that disperse and locate a mate and an unoccupied patch of
Wolves, one of the most widely distributed terrestrial mammals, can be found throughout much of the Northern Hemisphere where sufficient ungulate prey exists and the risk of being killed by humans is not excessive (Fuller et al. 2003). These two factors, prey biomass and human-associated mortality risk (and the resultant variation in wolf fecundity rate and survival rate, respectively) define the extent of suitable habitat for the Mexican wolf and other wolf subspecies (Fuller et al. 2003, Carroll et al. 2006, Mladenoff et al. 2009).

The gray wolf hunts in packs, primarily pursuing medium to large hoofed mammals, potentially supplementing its diet with small mammals (Mech 1970). Wolf density is positively correlated to the amount of ungulate biomass available and the vulnerability of ungulates to predation (Fuller et al. 2003).

Although vegetation and climate vary greatly across the range of the Mexican wolf, the region as a whole is generally more arid than regions of North America such as the Northern Rocky Mountains (NRM) to which wolves have previously been recovered (Brown 1983). Because of the semi-arid climate, primary productivity is generally lower than in the NRM (Carroll et al. 2006). In consequence, prey species available to wolves may be smaller in size, have lower population growth rates, exist at lower densities, and exhibit patchy distributions.

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 1219-1524m (4,500-5,000 ft) (Brown 1983). Wolves were known to occupy habitats ranging from foothills characterized by evergreen oaks (*Quercus* spp.) or pinyon (*Pinus edulis*) 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 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 (4,000-11,000 ft), ranging from semi-desert grasslands to conifer forests, with ponderosa forests dominating the area in between (USFWS 1996).

Wolf pack territories vary in size depending on prey density or biomass and pack size; minimum territory size is the area in which sufficient prey exist to support the pack (Fuller et al. 2003). Bednarz (1988) predicted that reintroduced Mexican wolves would likely occupy territories ranging from approximately 78 to 158 square miles (mi²) (200-400 square kilometers (km²), 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. Between 1998 and 2010, home range size of 80 denning packs in the Blue Range population averaged 182 mi² +/- 24 mi² (464 km² +/- 298 km² (179 mi² +/- 115 mi²) (John Oakleaf, pers. comm., 2012). The average home range size for 22 non-denning packs during the same time period was 330 mi² +/- 272 mi² (855 km² +/- 704 km²).

Pack home range size for denning packs has remained remarkably consistent since the beginning of this wolf recovery effort.

Wolves and Prey

Wolves play a variable and complex role in ungulate population dynamics depending on predator and prey densities, prey productivity, vulnerability factors, weather, alternative prey availability, and habitat quality (Boutin 1992, Gasaway et al. 1993, Messier 1994, Ballard et al. 2001). Ungulates employ a variety of defenses against predation (e.g., aggression, altered habitat use, gregariousness, migration) (MacNulty et al. 2007), and wolves are frequently unsuccessful in their attempts to capture prey (Mech and Peterson 2003, Smith et al. 2004). Generally, wolves tend to kill less-fit prey (e.g., young, old, injured) that are predisposed to predation (Mech and Peterson 2003, Smith and Bangs 2009). Wolves may reduce prey density, especially during periods of adverse weather or habitat 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).
Historically, Mexican wolves were believed to have preyed upon white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), collared peccaries (javelina) (*Pecari 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), but Mexican wolves may have consumed more vegetative material (Brown 1983:134) and smaller animals as do coyotes in southern latitudes (Hidalgo-Mihart et al. 2001).

Wolves are highly-adaptable prey generalists and available evidence suggests that Mexican wolves can efficiently capture a range of ungulate prey species of widely varying size. Elk have comprised the bulk of the biomass in the diet of wolves reintroduced to the Blue Range area of Arizona (Paquet et al. 2001, Reed et al. 2006, Carrera et al. 2008, Merkle et al. 2009a), and elk kill rates by Mexican wolves are similar to those for northern wolf subspecies (Oakleaf et al. in prep.). Data from the Blue Range indicate that elk are the preferred prey (Brown and Parsons 2001, Reed et al. 2006, Merkle et al. 2009a), with wolves showing a preference for calf elk over adult elk (AMOC and IFT 2005: TC-14). AMOC and IFT (2005) reported that wolf activity in the BRWRA appears to be located in areas of high elk density. Mexican wolves are also feeding on adult and fawn deer, other wild ungulates, cattle, small mammals, and occasionally birds (Reed et al. 2006). The difference between historical versus current prey preference is simply due to the lack of elk in historical Mexican wolf range except for very low densities at the northern periphery in central Arizona and New Mexico and yet elk are very common in the current Mexican wolf range in the BRWRA (AMOC and IFT: TC-1). Although white-tailed and mule deer are present, the Mexican wolves' preference for elk may be related to the gregariousness, relative abundance, naïveté, and consistent habitat use by elk. There is also a possibility some of the dominance of elk in their diet was skewed by data collection methods of analyzing only large scats in order to minimize the probability of including coyote scat (Reed et al. 2006, Carrera et al. 2008).
It is unlikely that this preference for elk leading to poor population performance (reference previous subsection where this is discussed?) in Mexican wolves. Elk are not especially difficult for Mexican wolves to prey on. Mexican wolf consumption rates are well within the range of other wolf populations (Mech and Peterson 2003) suggesting no difficulty killing elk or provisioning themselves. Given that all wolves are a group hunter, multiple wolves are involved in attacks on elk (MacNulty et al. 2012) which ameliorates the effect of larger quarry. Further, the size ratio of wolf to elk in the Blue Range (1:1) is no greater than wolves preying on bull bison in Yellowstone National Park (1:20) and wolves preying on bull moose (1:10) on Isle Royale suggesting that size of prey is not a good predictor of hunting success. Considering all the prey of Mexican wolves, they are less variable in size compared to other multi-prey wolf systems in North America (Mech and Peterson 2003). Studies of wolf hunting behavior in Yellowstone National Park also indicate that wolf hunting strategy is plastic and capable of adjusting for variously sized prey (MacNulty et al. 2009). In fact, virtually all wolves in a particular location (e.g. population) prey on more than one species of prey and wolf hunting strategies reflect this variability. For example, in Yellowstone one pack successfully preys on a range of species from deer to bison (Smith et al. 2004). Wolves have adapted their hunting strategy by varying age, size (males vs. females), behavior, and hunting group size all within one pack depending on the situation (Kaffmann et al. 2007) and species of prey indicating a wide adaptability to successfully capture a range of prey types (MacNulty et al. 2009a, MacNulty et al. 2009b, MacNulty et al. 2011). Deer and elk both flee (some elk may stand), whereas bison typically stand causing the same wolves to respond differently. For Mexican wolves, their primary prey - deer and elk - behave similarly making adjustment to each easier compared to other wolf populations with diverse prey. In short, while the historical literature indicates that Mexican wolves preyed primarily on deer (USFWS 1982, Brown 1983, USFWS 1996), current research shows successful adaptation to elk with normal to high consumption rates and even a preference for elk when they are sympatric with deer.

Kill rates of individual wolves vary significantly, from 0.5 to 24.8 kg/wolf/day (1 to 50 lbs/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 (3 lbs/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 (15 lbs/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 (29/year) or 1 white-tailed deer every 8-9 days (43/year, Johnson et al. 1992). Stark
et al. (in prep) used clusters of wolf GPS locations to estimate kill rates of Mexican wolves in the
BRWRA and estimated a kill rate of 6.53 kg/wolf/day in early winter (assuming 68% of an elk is
edible biomass), and a 9.42 kg/wolf/day consumption rate in late winter (March), for an overall
winter estimate of 8.59 kg/wolf/day. Most studies in other wolf/ungulate systems show a lower
kill rate in the summer (perhaps only 70% of winter kill rates) due to a higher diversity of food
(in prep.), an independent analysis by the SPS estimated each Mexican wolf would kill 19.9 elk
per year if feeding on only elk. Assuming elk comprise 80% of the biomass consumed and deer
comprise 8%, each wolf would annually kill approximately 16 and 6.5-11 elk and deer (both
species), respectively.

Ungulate population dynamics in the Southwest differ from that of the same species in other
ecoregions due to the lower overall primary productivity of the habitat (Short 1979). Vegetative
communities in the arid southwestern forests are not as lush and productive as similar-looking
communities in the Rocky Mountains. The lower productivity of the vegetative community
influences productivity upwards through several trophic levels resulting in lower inherent
herbivore reproductive rates in the Southwest than in their northern counterparts (Heffelfinger
2006:156). In addition, recruitment differs between southwestern and northern ungulate
populations because winter precipitation comes as rain rather than snow. Lack of widespread
winterkill of ungulates means that lower recruitment is needed to sustain a stable population
compared to northern ungulate populations. The bimodel rainfall patterns in most of the
Southwest provides for nutritional peaks in the late summer and winter/spring periods.
Southwestern deer herds require 35-50 fawns per 100 does to remain stable (Heffelfinger
2006:158), while those in the northern Rocky Mountains require 66: fawns 100 does for
population maintenance (Unsworth et al. 1999). As in deer, southwestern elk seem to have adopted
a life history strategy of lower overall recruitment and higher survival.
Wolves may also impact ecosystem diversity beyond that of their immediate prey source in areas where their abundance affects the distribution and abundance of other species (sometimes referred to as “ecologically effective densities” (Soule et al. 2003, 2005). For example, in a major review of large carnivore impacts on ecosystems, Estes et al. 2011 concluded that structure and function as well as biodiversity is dissimilar between systems with and without carnivores. In the Southwest, the dominant carnivore is the wolf, so one should expect that wolf recovery, along with other carnivores, could have significant impacts on biodiversity and ecosystem processes. This may occur through two mechanisms: a behavioral mediated or numeric response on prey – or both (Terbough et al. 1999). Such effects have been attributed to gray wolf reintroduction in Yellowstone National Park and elsewhere (e.g., Ripple and Beschta 2003, Wilmers et al. 2003, Ripple and Beschta 2004, Hebblewhite et al. 2005, Ripple and Beschta 2011). Such a trophic cascade was caused by wolf effects on elk (numeric/behavioral or both is yet to be determined) which caused a response in willow which in turn created habitat and forage for songbirds and beavers (Hebblewhite and Smith 2010, Baril et al. 2011). Impacts like this may be an outcome of wolf recovery in the Southwest. However, wolves have yet to have a demonstrable trophic cascade effect in the BRWRA likely due to the low densities of Mexican wolves in the area (Beschta and Ripple 2010).

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 were 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 population objective of at least 100 Mexican wolves, depredation levels of 1-34 cattle per year would occur (USFWS 1996). Between 1998 and 2012, x confirmed cattle depredations were documented, or an average depredation rate of x cattle per 100 wolves per year. This depredation rate may represent an underestimate due to incomplete detection of wolf-killed cattle, which has been demonstrated in XXXX(Oakleaf et al. 2003, Breck et al. 2011). Between 1998 and 2012, xx wolves were removed as a result of xxx
confirmed depredations (xxx cattle, xx sheep, and x horses) (USFWS our files), or one wolf
removal per xx 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).

Observations 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, Merke et al. 2009). 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 (cite?) or
preying on elk directly (Gese et al. 1994), 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 when coyotes visit wolf kills to
scavenge (Carrera et al. 2008), as has been documented in Yellowstone National Park (Merkle et
al. 2009b).

Bednarz (1988) 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 was not provided (USFWS 2004, USFWS 2006a, USFWS 2009: Population Statistics).

**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, reared in captivity with frequent human contact or otherwise habituated to humans 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 wolves are not considered a threat to human safety (McNay 2002). An inquest jury has attributed one recent human death in Canada to wolves, although a number of wildlife experts disagree whether wolves or black bears were responsible for the death (citation). During March 2010, a women jogging alone in rural Alaska was killed by wolves (Butler et al. 2011).

Wolves are also less dangerous (as measured by attacks/carnivore) than other carnivores already present (black bears and cougars) throughout the southwest.

In the BRWRA, wolf-human interactions have been documented. For example, between 1998 and 2012, xx cases of wolf-human interactions were documented in the BRWRA. The majority of these incidents (xx percent) were considered investigative searches in which wolves ignored human presence. In several cases (xx percent), wolves approached humans in a non-threatening manner, and in x reports wolves displayed aggressive behavior (charging) toward humans (USFWS our files). 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 above (including xx charges, in which the aggression appeared to focus on the dogs rather than the humans) (USFWS our files). Aversive conditioning (rubber bullets, cracker shells) or translocation or removal of the wolf was applied.

Humans also can 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. 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). Past recommendations estimated suitable Mexican wolf habitat to occur where human density is less than 12 people per square mile (2.56 km²), with an optimum density of less than 6 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 0.31/km² or 0.8/mi² prior to the reintroduction) (USFWS 1996: Table 3-3). In the BRWRA, illegal shooting is the biggest mortality source for Mexican wolves (USFWS 2009: Population Statistics) (and see “Physical Description and Life History”, and factor (E) in “5-factor analysis”).
I. The Geography of Recovery

(IMPORTANT Note to Reviewer: This subsection is not standard in a recovery plan. I have swapped out the “Critical Habitat” section that typically occurs here in the recovery plan with this one, based on the FWS recovery planning guidance, “If important habitat has been identified as needed for recovery but has not been designated as critical habitat, be sure to note this in this section and include the necessary management of the habitat in the recovery actions section.” We can/will make clear that the areas discussed here are NOT being recommended for critical habitat / that critical habitat cannot be designated for 10j species. Rather, this subsection provides an opportunity to broadly explain what the Southwestern landscape looks like from the perspective of the wolf recovery effort. Thus at minimum it should contain a description of ecologically suitable habitat; it could also include an overview of non-ecological factors that the team wants acknowledged, such as land ownership (including tribal lands), land use, binational aspects, etc. We need additional team discussion about what might be useful and appropriate in this section, but this may be the place to address some of the non-biological concerns raised at our August and November 2011 meetings. As I think about this section more, it may be better placed AFTER the recovery criteria…we need to flesh it out and see where it fits the best.)

Because Mexican wolf recovery will require reintroduction projects to restore populations it is essential to define the region where such efforts would be scientifically sound and ecologically feasible. It is also important to carefully assess the major social, cultural, political, and economic characteristics of the region that may influence implementation of Mexican wolf recovery activities. Defining the ecological basis for Mexican wolf recovery includes consideration of historical range and current range, and current and future habitat conditions, including, most importantly, prey availability. This information is given context by the policy framework created by applicable federal, state, and international laws and regulations, as well as by social aspects of this region pertinent to Mexican wolf recovery such as land ownership, tribal boundaries, international relations with Mexico, and ranching and other economically and culturally significant land uses that have potential to conflict with wolf recovery. This subsection of the plan provides a holistic description of the landscape within which Mexican wolf recovery is ecologically appropriate and biologically feasible. We first describe initial analyses of potential Mexican wolf habitat that occurred prior to the widespread availability of
digital data on habitat attributes. We then discuss how the two factors limiting wolf distribution
(prey abundance and mortality risk) have been evaluated in more recent studies using geographic
information systems (GIS). Because of the contrasts in available digital data between the US and
Mexico, we review habitat distribution in each nation separately. The available digital data in the
two nations allows us to make quantitative comparisons between sites within each nation, but
only qualitative comparisons of sites between nations.

*Initial Analyses of Habitat Suitability in the United States*

In the course of planning for Mexican wolf recovery in the 1990s, the FWS evaluated the habitat
suitability of five potential core areas in Arizona and New Mexico (with those within each of the
two states being evaluated separately). Bednarz (1989) evaluated the suitability of the White Sands Missile Range (WSMR, see Figure 1 for this and other locations) in central New Mexico,
finding it suitable in terms of habitat security but marginal in habitat productivity (prey abundance). A later assessment concluded that the area could only support 20 to 30 wolves
(Green-Hammond 1994). Johnson et al. (1992) evaluated four areas in Arizona: the Blue, Galiuro-Pinaleno, Chiracahua, and Patagonia-Atascosa ranges (Figure 1). The New Mexico
portion of the current Blue Range Wolf Recovery Area (BRWRA) was not considered in either
Johnson et al. (1992) or Bednarz (1989). The Arizona portion of the BRWRA was scored by
Johnson et al. (1992, see also Groebner et al. 1995) as highest in 7 of 13 habitat factors. The Atascosa/Patagonia ranges were the only one of the remaining three areas to approach the
BRWRA in quality (highest in 5 of 13 habitat factors). Parsons (1995) produced a
comprehensive reassessment of all 5 of the proposed sites in Arizona and New Mexico. He found
that, based on the sum of scores for seven factors affecting wolf habitat suitability (habitat area,
ingulate density, water availability, livestock density, human density, road density, and effects
on threatened species), WSMR scored highest, followed by the Blue Range, and more distantly, the Atascosa/Patagonia Mountains. The contrast between these results and those of others who
discount the potential of the WSMR (e.g., Paquet et al. 2001, Carroll et al. 2005), is due to the fact that habitat area, for which WSMR scores very low, is only one of seven factors given equal
USFWS (1996) evaluated four alternatives for Mexican wolf restoration and chose a preferred alternative involving reintroduction to the BRWRA, with potential use of WSMR as a second core area if necessary. In the evaluation of Alternative D (No action or natural recolonization), it was estimated that if successful wolf dispersal from Mexico occurred, this might eventually result in 30, 20, and 5 wolves inhabiting southeastern Arizona, southern New Mexico, and Big Bend National Park (Texas), respectively, based on habitat potential there.

Sneed (2001) evaluated suitability of wolf habitat in the Grand Canyon and Mogollon Rim region in northern and central Arizona. While this area includes some habitat with relatively low ungulate density due to the arid climate, other portions of the area such as the Kaibab Plateau support ungulate densities comparable to mesic forest ecosystems of the NRM (> 8 deer/km²). Sneed (2001) concluded that the North Kaibab and South Colorado Plateau could support between 115 and 187 wolves.

GIS Assessment of Habitat Suitability in the US: Factors Associated with Wolf Fecundity

Ideally, estimates of potential wolf fecundity would be based on surveys of abundance of prey species. However, these data are challenging to assemble across a multi-state region because methods for estimating ungulate abundance vary between jurisdictions. A comprehensive survey of available data on prey abundance in the US was developed as part of this recovery plan, and is discussed below.

Because best available data on prey abundance is inconsistent between areas in methodology and resolution, it is also useful to evaluate potential wolf fecundity based on surrogate variables for prey productivity that are consistently measured for the region as whole. Past studies have found good concurrence between such surrogate metrics and actual prey abundance in Colorado and Utah (Carroll et al. 2003a, Carroll 2003). The drawbacks of estimating a factor more distantly related to wolf fecundity may be outweighed in some cases by the benefits of obtaining consistent and comparable data across a wide region. However, ungulate abundance may differ between two areas with similar vegetation but contrasting levels of hunting pressure by humans. Although prey species in the US are often managed near carrying capacity, in some areas of
Mexico prey abundance may be locally depleted by heavy hunting pressure, lowering the match between vegetation productivity and prey abundance (i.e., wolf habitat) (Lara-Diaz et al. 2011).

Carroll et al. (2005, 2006) developed a binational evaluation of habitat for the Mexican wolf using predicted prey abundance based on vegetation data (Figures 1 & 2). The National Land Cover Dataset (NLCD) was used for the United States. NLCD data were derived from Landsat TM imagery at a resolution of 30 m, and contains 21 landcover classes. Landcover types from both the US and Mexican data sets were ranked as to their value as wolf habitat (see Tables 4 and 5 in Carroll et al. 2005) based on expert opinion and historical records (Brown 1983, C. Lopez-Gonzalez pers. comm.).

Because ungulate prey density may vary greatly within a particular vegetation type due to variation in primary productivity and other factors, Carroll et al. (2005, 2006) augmented the vegetation data with a satellite imagery-derived metric, tasseled-cap greenness (Crist and Cicone 1984). Variables such as greenness that are derived directly from unclassified satellite imagery are correlated to varying degrees with ecological factors such as net primary productivity and green phytomass that influence the abundance of ungulates (Cihlar et al. 1991, Merrill et al. 1993, White et al. 1997). Summer greenness values were found to be strongly correlated with ungulate density in the northern Rocky Mountains and Pacific Northwest (Carroll et al. 2001b, 2003a).

Carroll et al. (2005, 2006) combined greenness levels with ranking of vegetation types to produce a composite ranking (Figure 2). This prey productivity or potential fecundity layer also incorporated the negative effect of terrain (slope) on prey availability to wolves (Paquet et al. 1996). Because the season of maximum productivity varies across the region, Carroll et al. (2005, 2006) used the maximum greenness level found in either March or July (2001) MODIS imagery.

GIS Assessment of Habitat Suitability in the US: Factors Associated with Wolf Survival

As with fecundity estimates, wolf survival estimates in different habitat types would ideally be based on models of the relationship of habitat variables to wolf survival from other recovery areas such as the NRM. However, although analysis of NRM survival data has occurred (e.g., Murray et al. 2010), these studies have not yet produced models of the relationship between...
survival and habitat variables as has been done for other carnivore species (e.g., grizzly bears; Schwartz et al. 2010). However, a large body of literature links wolf survival with surrogates for human lethality such as roads and population (reviewed in Fuller et al. 2003). Because much of this data comes from areas without the public lands grazing patterns found in the western US, less is known about the quantitative effects of livestock density (Figure 3), and resulting depredation-related removals, on wolf survival (but see Treves et al. 2011 for an example from the Great Lakes states).

Previous studies have incorporated “habitat effectiveness” as a composite metric for relative mortality risk to large carnivores based on roads and human population (Figure 4). This has proven to be a useful surrogate for wolf mortality risk in the northern Rocky Mountains (Merrill et al. 1999, Carroll et al. 2003a, 2003b). In the analysis of Carroll et al. (2005, 2006), roads data for the US were derived from USGS Digital Line Graphs (DLG) coverage at 1:100,000 scale (USGS, unpublished data) (Figure 4).

Population data for the US was derived from 1990 and 2000 censuses (US Census Bureau 2001) at the census block scale. Human population growth from 2000 to 2025 was predicted based on growth rates from 1990 to 2000. Road density was predicted to increase at 1% per year (Theobald et al. 1996). Data on livestock abundance for the US was derived from the 1997 US Census of Agriculture at the county level (Figure 3). Livestock data are therefore at a substantially coarser scale than available human population data.

Identification of Potential Core Areas of Suitable Habitat within the US

Once data on both potential wolf fecundity and survival is collected, one is faced with the challenge of estimating the relative influence of habitat factors related to fecundity and survival in determining persistence of wolf populations. For example, habitat suitability for southwestern Colorado (which has very high prey abundance and moderate human impacts) may be contrasted with habitat suitability for the Grand Canyon region and western Texas (which have lower prey abundance and lower human impacts (roads and population centers)). Similarly, arid ecosystems in many areas of the southwestern US show relatively low human impacts but also show prey abundance near the lower threshold for wolf persistence. Because previous reintroductions in the
western US were to sites in the Greater Yellowstone Ecosystem and central Idaho which have both high prey abundance and low human impacts, they do not provide detailed guidance as to the relative strength of these two factors.

An effective strategy for wolf recovery involves establishing well-distributed source populations in core areas of highly suitable habitat and then allowing natural dispersal to re-establish a regional metapopulation. To merit attention as a potential reintroduction site, a ‘core area of suitable habitat’ would need to be both be relatively secure habitat and be well situated to facilitate growth of the regional wolf metapopulation. The several habitat suitability assessments that have been conducted over the last 20 years indicate that only three major core areas of suitable habitat exist in the area encompassing the Mexican wolf’s historical range and adjacent areas in Arizona, New Mexico, southern Colorado and southern Utah that are capable of supporting Mexican wolf populations of sufficient size to contribute to recovery. The three core areas of suitable habitat are 1) the Blue Range Wolf Recovery Area and adjacent public lands, 2) the Grand Canyon and adjacent public lands in northern Arizona and southern Utah (as circumscribed by interstate highways 15 and 70), and 3) two linked areas of public lands and private lands with conservation management in northern New Mexico and southern Colorado (as circumscribed by interstate highways 70 and 25) (Table 1). We describe these areas using regional-scale habitat data, but a more detailed evaluation of local land ownership, land use, and prey abundance patterns would be necessary in subsequent stages of recovery (e.g., development of an Environmental Impact Statement before conducting reintroductions to restore populations that count toward recovery). An additional area in western Texas which has some attributes of suitable habitat is also described here.

All these areas are projected to become more distinct and separated as landscape change factors such as exurbanization continue (Carroll et al. 2006). All areas except western Texas include large tracts of public lands subject to conservation mandates (National Park, wilderness) where wolves are predicted to experience the lowest human-induced mortality. While the Grand Canyon and northern Arizona and southern Utah core area and northern New Mexico/southern Colorado core area are both located north of the Mexican wolf’s historical range, in the recent past they each supported a closely related subspecies (C. l. nubilus) that has for over half a
century been restricted to the western Great Lakes states and Canada due to 20th century extermination campaigns. The two areas are proximate to (Brown 1983, Bogan and Mehlhop 1983, Hoffmeister 1986, Nowak 1995) or well within (Leonard et al. 2005) the zone of gray wolf subspecies intergradation that characterized the southwest historically.
Table 1. Ecological attributes of core areas of suitable Mexican wolf habitat. All metrics are expressed as per km$^2$ unless noted. Isolation is center-to-center distance from nearest neighboring potential core area. Wolves per 1000 km$^2$ is based on the model of Fuller et al. (2003). ‘Total wolves’ indicates estimates of potential population size based on previously-published studies and the analysis in this document.

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<th>Area name</th>
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<th>Total wolves</th>
<th>Isolati $\text{on}$ (km)</th>
<th>Cattle</th>
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<th>Deer Biomass</th>
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<td></td>
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</tr>
<tr>
<td>4. Sierra de Valparaiso/Sierra de Urca/Mezquital</td>
<td>12,667</td>
<td>350</td>
<td>6</td>
<td>1-2</td>
<td>0.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Maderas del Carmen/Serranias de Burro</td>
<td>19,564</td>
<td>250</td>
<td>6</td>
<td>1-2</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Sierra Plegada</td>
<td>17,968</td>
<td>450</td>
<td>7</td>
<td>1-2</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Description of Core Areas of Suitable Habitat in the US

1. Blue Range: The Blue Range Wolf Reintroduction Area (BRWRA) is located on the Apache-Sitgreaves and Gila National Forests (NFs) along the Arizona/New Mexico border. Since 1998 the FWS has released Mexican wolves into this area. The Mogollon Rim area lies along a block of forested public lands (e.g. Tonto NF) stretching between the Blue Range and Grand Canyon sites. The two areas (Blue Range and the Mogollon Rim) would likely function as a semi-continuous block of suitable wolf habitat in the absence of management actions to limit wolf populations or movement. However, Carroll et al. (2006) concluded that the wolf survival would be lower in the Mogollon Rim area than in the Blue Range due to greater levels of threat factors (primarily roads) in the former area. We do not identify the Mogollon Rim as a separate core area of suitable habitat both because of its greater threat levels and because it does not represent a geographically disjunct block of potential wolf habitat that would support a spatially and demographically distinct population.

2. Grand Canyon (Northern Arizona/Southern Utah as circumscribed by interstate highways 15 and 70): This core area encompasses the Grand Canyon and adjacent public lands in northern Arizona and southern Utah. The area is centered on the Grand Canyon National Park (4900 km²) and adjacent of Kaibab and Coconino NF lands (13,300 km²). The Grand Canyon National Park is not predominantly highly productive wolf habitat, although wolves within its boundaries would likely benefit from low rates of human-associated mortality. Adjacent public lands on the Kaibab Plateau, other portions of the Kaibab National Forest, and areas in southern Utah such as the Paunsaugunt Plateau are more mesic with greater prey densities as described below.

With the exception of the Blue Range, the Northern Arizona/Southern Utah core area may have the highest probability of enhancing regional wolf populations through dispersal (Carroll et al. 2005, 2006). This is due to both a large area of public lands with low mortality risk for wolves, and substantial connectivity from that habitat southward through the Mogollon Rim towards the Blue Range and northward to the public lands of the mountains of southern and central Utah and beyond to Wyoming and Idaho.
3. Carson/San Juans (Northern New Mexico/Southern Colorado as circumscribed by interstate highways 70 and 25): This core area of suitable habitat encompasses two linked areas of public lands and private lands with conservation management in northern New Mexico and southern Colorado. The New Mexico portion of this area includes sections of the Carson National Forest (6,000 km²), Santa Fe National Forest (6,400 km²), Vermejo Park Ranch (2,300 km²), and 268 km² of additional private lands protected under conservation easements, and the Taos Pueblo (391 km²) of which 230 km² are managed as wilderness by the tribe. The Valle Vidal Unit of the Carson National Forest (407 km²) is managed with special emphasis on wildlife and fisheries resources. For example, 88% of the roads present in 1982 have since been closed or removed to enhance wildlife and fisheries habitat. Given tightly restricted access to Vermejo Park Ranch, it is functionally roadless.

The Colorado portion of this area extends across portions of the San Juan National Forest (8,345 km²), Rio Grande National Forests (7,440 km²), and Grand Mesa, Uncompahgre, and Gunnison National Forests (12,600 km²). The San Juan Mountains contain 4,000 km² of Wilderness Areas and 4,000 km² roadless areas including significant lower-elevation ecosystems. Relatively low levels of livestock grazing occur on the San Juan NF (Bennett 1994).

4. Western Texas: Approximately 24,000 km² of potentially suitable habitat occurs in western Texas (Carroll et al. 2006). This area is assessed as suitable in the model of Carroll et al. (2005) due primarily to low numbers of roads and human settlements. Potential prey productivity is low but likely sufficient to support low densities of wolves (Table 1). This area lies between the Davis Mountains and the Pecos River watershed in Jeff Davis, Brewster, Pecos, Terrell and Val...
Verde Counties, from approximately State Route 385 on the west to State Route 163 on the east. The few public landholdings (Davis Mountains State Park, Seminole Canyon State Park) in this area are relatively small in size. Private lands under conservation easements total approximately 270 km. Big Bend National Park, while large in size, lies to the south of this area and does not offer extensive suitable habitat due to its aridity. The area of suitable habitat in western Texas is distant (700km) from the nearest core area of suitable habitat in New Mexico, but relatively near (250km) the potential reintroduction area in the northern Coahuila identified by Araiza et al. (2006).

Other Areas of Arizona and New Mexico

The US/Mexico border region is likely to serve as sink habitat for wolves under current conditions (Carroll et al. 2006) despite the presence of some potentially suitable habitat such as the 305 km² Galiuro Wilderness. Sites in this area that have previously been proposed as reintroduction locations (e.g., Galiuro/Pinaleno, Chiricahua Mountains, and Atascosa/Patagonia Mountains [Johnson et al. 1992]) appear, based on the model of Carroll et al. (2005), to not be optimal choices for such efforts. However, the area’s key role in facilitating dispersal between US and Mexican wolf populations suggests that it be given significant attention in recovery planning, through recovery actions which increase the likelihood of these sites being naturally recolonized by dispersers from the Blue Range or Mexican populations. The importance of binational population connectivity is further highlighted by the recent release of Mexican wolves in northern Sonora ~100 km south of the Arizona/New Mexico border.

Data on Prey Distribution and Abundance in the US

Carroll et al. (2003a, 2005, 2006) used spatially explicit population models (SEPM) to assess the potential of prey populations to support wolf populations in the southwestern US with differential emphasis on the three core areas of suitable habitat. Abundance estimates of ungulate prey are not collected in some areas of the western US and where they do exist they show strong inconsistencies across state boundaries. Therefore, as a surrogate for ungulate abundance they used tasseled-cap greenness (Crist and Cicone 1984), a metric derived from MODIS (Moderate Resolution Imaging Spectroradiometer) satellite imagery from mid-July 2003 and 2004 (Wharton and Myers 1997). “Pseudo-habitat” variables such as greenness are
correlated to ecological factors like net primary productivity and green phytomass (Cihlar et al. 1991, Merrill et al. 1993, White et al. 1997) and thus with ungulate abundance (Carroll et al., 2001b, 2003a). Furthermore, the large body of published research on relationships between wolf demographics and habitat (as reviewed by Fuller et al. 203) strengthens the power of conceptual models such SEPM. SEPM for the Blue Range, Grand Canyon, and northern New Mexico/southern Colorado core areas indicated that prey populations were sufficient to support > 250 wolves (Table 1) (Carroll et al. 2005, 2006).

As a validation of the GIS modeling that used a surrogate variables to estimate prey populations (as described above), the recovery team assembled ungulate abundance estimates from game surveys for selected areas in the US portion of the region (J. Heffelfinger et al., unpubl. data). These data were provided primarily by the state game departments of Arizona, New Mexico, Utah, and Colorado. Survey and population estimation methodology varied between jurisdictions but data were reduced to animal density as a common denominator. Survey data were summarized at the spatial resolution of game management units (GMU), with the exception that New Mexico summarized data over general regions. Members of the SPS calculated a standard Ungulate Biomass Index (UBI) for several areas of interest (Fuller et al. 2003). Using estimated densities of elk, white-tailed deer, and mule deer from several areas considered in this document as potential recovery areas, the resultant UBI was calculated and compared to a regression equation showing the relationship between UBI and wolf density in 31 studies throughout North America (Fuller et al. 2003, fig. 6.2). Based on this regression equation, wolf density would be estimated at 21 wolves/1000 km\(^2\) for the Blue Range/Mogollon Rim, 17 wolves/1000 km\(^2\) for the Grand Canyon area, and 28 wolves/1000 km\(^2\) for Northern New Mexico/Southern Colorado (J. Heffelfinger et al., unpubl. data). Since elk make up a majority of the Mexican wolf diet, the same exercise was conducted for elk alone yielding wolf density estimates of 18, 12, and 25 wolves/1000 km\(^2\) for the Blue Range/Mogollon Rim, Grand Canyon area, and Northern New Mexico/Southern Colorado areas, respectively.

These predicted wolf densities were extrapolated to previously-identified core areas using hexagons of >60% predicted wolf occupancy from spatially-explicit models (Figure XX, Carroll et al. 2006). Respective wolf densities for the core areas were applied to the number of 500 km\(^2\)
hexagons with at least 60% probability of occupancy to estimate the total number of wolves that
could be supported in these areas. These calculations indicate each of the three core areas
identified are of sufficient size and have the beginning biomass to support > 250 wolves (Table
2).

The resulting estimates of wolf densities and corresponding estimates of population size that can
be expected to persist in the US core areas should be viewed cautiously. Game management
units and occupancy polygon boundaries did not correspond exactly to the potential core areas of
suitable habitat, so predicted densities and numerical values are approximations. Additionally, it
is uncertain to what extent the regression equation of Fuller et al. (2003) applies to less
productive arid southwestern environments where ungulate population dynamics may differ to a
degree from those in mesic ecosystems. Seasonality of prey availability and vulnerability may
also affect wolf carrying capacity differently in areas where altitudinal migration of ungulates
occurs, versus areas that receive little or no snow. These shortcomings notwithstanding,
extrapolating each density estimate across the respective core areas affirmed that the US portion
of the Mexican wolf recovery area could potentially support > 1000 wolves (Table 2).

<table>
<thead>
<tr>
<th>Core Area</th>
<th>Area (km²) with 60%+ Predicted Wolf Occupancy</th>
<th>UBI based on all Deer &amp; Elk</th>
<th>Predicted wolf density (/1000km² based on Deer &amp; Elk)</th>
<th>Predicted No. of Wolves (based on Deer &amp; Elk)</th>
<th>UBI based on Elk only</th>
<th>Predicted wolf density (/1000km² based on Elk only)</th>
<th>Predicted No. of Wolves (based on Elk only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO/NM Border</td>
<td>11,500</td>
<td>7.6</td>
<td>28</td>
<td>322</td>
<td>6.5</td>
<td>25</td>
<td>288</td>
</tr>
<tr>
<td>Grand Canyon/UT</td>
<td>23,000</td>
<td>4.1</td>
<td>17</td>
<td>391</td>
<td>2.6</td>
<td>12</td>
<td>276</td>
</tr>
<tr>
<td>Mogollon Rim/BRWRA</td>
<td>20,500</td>
<td>5.6</td>
<td>22</td>
<td>442</td>
<td>4.5</td>
<td>18</td>
<td>369</td>
</tr>
</tbody>
</table>

Table 2. Based on ungulate biomass and their areal extent each of the three core areas identified
are expected to support > 250 wolves.
Potential effects of landscape change on wolf habitat are summarized based on the results of Carroll et al. (2006). That study estimated potential change in human-associated impact factors (i.e., roads and human population) by proportionately increasing road density and by increasing human population on the basis of current trends derived from a time series of human census data. The study predicted human population growth from 2000 to 2025 based on growth rates from 1990 to 2000, but adjusted the predicted 2025 population to match state-level predictions based on more complex socioeconomic models. Road density projections incorporated an increase of 1% per year (proportional to the current road density at the 1-km$^2$ scale), a rate half of that seen in the most rapidly growing portions of our study region (e.g., western Colorado; Theobald et al. 1996).

Wolf habitat in New Mexico and Colorado are most vulnerable to landscape change because habitat in those states is relatively more fragmented than in Arizona and is experiencing more rapid development. Outside of those two states, the US southwest shows vulnerability levels similar to those in the US Northern Rockies - about a 25% decline in wolf carrying capacity over 25 years (Carroll et al. 2003, 2006). Carroll et al. (2005, 2006) predicted that, absent management actions to mitigate threat factors, future wolf populations in the southwestern US may be primarily confined to high quality or source habitat in the core areas previously discussed. Connectivity between the Blue Range and the Sierra Madre Occidental (Sonora/Chihuahua) would be only tenuously maintained via occupied habitat along the Arizona/New Mexico border.

Earlier studies concluded that potential wolf population connectivity between the Blue Range and Grand Canyon core areas is greater than between the Blue Range and the northern New Mexico/southern Colorado core area (Carroll et al. 2005, 2006). We analyzed potential connectivity in more detail using the Connectivity Analysis Toolkit software (Carroll et al. 2011). We used a habitat model based on data used in previous studies (Carroll et al. 2006) as
input to an analysis of shortest-path betweenness centrality and current-flow betweenness centrality (BC) (Carroll et al. 2011). Shortest-path BC identifies the single best linkage between each pair of core areas, whereas areas of high current flow BC reveal connectivity 'pinchpoints' where much potential dispersal flow is being routed through relatively limited habitat. Results indicate that the best linkage in the southwestern US corresponds to a rate intermediate between the well-connected populations in the northern Rocky Mountains (i.e., Greater Yellowstone to central Idaho and central Idaho to northwestern Montana) and the poorly connected populations (i.e., Greater Yellowstone to northwestern Montana). Recovery actions designed to facilitate dispersal between populations in the southwestern US (especially those that reduce or eliminate human-caused mortality) will be critically important to recovery and may focus on the most important shortest-path linkages while giving additional attention to areas with high current flow as well. Such recovery actions may be essential in ensuring that connectivity-related recovery criteria are achieved.

Results of Previous GIS Analyses of Habitat Suitability in Mexico
In Mexico, several previous analyses have evaluated the extent of potential habitat. Araiza et al. (2002) evaluated GIS data from Sonora, Chihuahua, and Coahuila and identified an area in the northern Sierra Madre Occidental with relatively high levels of habitat security (low road density and human settlement). However, field measurements of prey abundance indicated deer densities in this area were near the lower limit for wolf persistence. This suggested that augmentation of deer herds through revised grazing techniques and reduced hunting might be necessary before the area could support wolves (Araiza 2002).

Sanchez and Guevera (2006) examined habitat potential in Coahuila and Nuevo Leon and identified areas of as potential habitat in northern Coahuila (Sierra del Carmen) and central Nuevo Leon (Sierra Plegada). Servín et al. (2007) analyzed historic wolf distribution records using the GARP method and regional-scale GIS data on vegetation type, elevation, temperature, and precipitation to define the probable historic distribution and ecological niche of the Mexican wolf. Areas with land use unsuitable for current occupation by wolves (human-altered habitats) were then excluded from the historic distribution to produce an estimate of the area of remaining suitable habitat. A large portion of the Sierra Madre Occidental (90,000 km²) was predicted to be
suitable for wolves under these assumptions, whereas little habitat remained in other areas such as Nuevo Leon and Tamaulipas (Servin et al. 2007).

Carroll et al. (2005) identified and compared four potential core areas of suitable habitat in Mexico: the Sierra San Luis (northern Chihuahua/Sonora), Maderas del Carmen (northern Coahuila), an area in northwestern Durango near the Chihuahua border, and the Tutuaca reserve area (west-central Chihuahua near the Sonora border). Of the four, the Durango site contained the most productive habitat for wolves, but the Tutuaca and Maderas del Carmen sites appeared to have lower risk of conflict with livestock production.

Martinez Meyer et al. (2006) developed a habitat model based on climate, vegetation, and human impacts (roads and human population centers)(Figure 5). The study predicted that only 2% of the area with suitable climate and vegetation also showed low human impacts. These core areas of potential habitat were found widely distributed across northern Mexico in small patches (<100 km\(^2\) in size). Of the 7,265 km\(^2\) of currently suitable habitat with low human impacts, 2,284 km\(^2\) was predicted to retain suitability under future climate.

Martinez-Gutierrez (2007) identified two areas of >600 km\(^2\) in size in the northern Sierra Madre Occidental (western Chihuahua near the border with Sonora) with habitat suitability and low human-associated mortality risk (Figure 6). The more southerly of these areas falls within the Tutuaca core area (see below). Additionally, several additional areas of between 200 and 500 km\(^2\) in size were identified in the same region of northern Sierra Madre Occidental as well as in western Durango.

**Habitat Factors Associated with Wolf Fecundity: Vegetation Data for Mexico**

Several studies, including Carroll et al. (2005, 2006), have used vegetation data from the 2000 National Forest Inventory (Palacio-Prieto et al. 2000). This data mapped land cover across Mexico at a scale of 1:250,000 based on Landsat TM imagery. Land cover was assigned to one of 75 classes, with a minimum mapping unit (MMU) of approximately 1 km\(^2\). The vegetation data (Palacio-Prieto et al. 2000) for Mexico is the first detailed national vegetation data set for
the area and provides a more accurate record of human impacts (i.e., human-altered land cover types) than did the Mexican roads data described below.

Habitat Factors Associated with Wolf Fecundity: Climate Data for Mexico

Species distribution models based on climate data are termed “climatic niche” models. These models are most commonly applied to allow first approximations of potential effects of global climate change on large suites of taxa (Thomas et al. 2004). Because many of these species are poorly-known, and relevant non-climatic environmental variables may be unavailable over the global or continental extent of analysis, more detailed and biologically-informed models may not be feasible. Servín et al. (2007) and Martinez Meyer et al. (2006) used the Genetic Algorithm for Rule-set Prediction (GARP) to predict the potential distribution of the Mexican wolf. Stockwell and Peters (1999) proposed that the GARP method they developed identifies the ecological niche of a species, defined as the multi-dimensional environmental space which contains those ecological conditions under which the species can maintain populations without immigration (Grinnell 1917, MacArthur, 1972). As climatic niche models are increasingly applied to inform single-species conservation strategies, the assumption that such models adequately describe a species “fundamental niche” have been questioned, particularly when the mechanisms by which climate influences physiology and demography of the species of interest are unknown (Elith and Leathwick 2009). Although climatic niche models might be expected to suggest overarching limiting factors within which finer-scale habitat relationships operate, results may be misleading in the absence of relevant finer-scale habitat variables (Pearson and Dawson 2003, Carroll 2010).

To develop input data for GARP, available occurrence points are divided evenly into training and extrinsic test data sets; the former set is again divided evenly into true training data (for model rule development) and intrinsic test data sets (for model rule evaluation and refinement). Although input data was derived from historical records, GARP projects results onto current landscapes to estimate the current geographical distributions of suitable areas. GARP is designed to work based on presence-only data; absence information is included via sampling of pseudo-absence points from those pixels where the species has not been detected. GARP works in an iterative process of rule selection, evaluation, testing, and incorporation or rejection: firstly, a method is chosen from a set of possibilities (e.g. logistic regression, bioclimatic rules), and is...
then applied to the training data and a rule developed; rules may evolve by several means (truncation, point changes, crossing-over among rules) to maximize predictivity. Predictive accuracy (for intrinsic use in model refinement) is then evaluated based on 1,250 points resampled from the intrinsic test data and 1,250 pseudo-absence points. Change in predictive accuracy between iterations is used to evaluate whether particular rules should be incorporated into the model, and the algorithm runs either 1,000 iterations or until convergence.

Martinez Meyer et al. (2006) predicted Mexican wolf distribution based on a niche model developed with data on topography (elevation, slope, aspect, topographic index) and annual means of climate variables (diurnal temperature range, precipitation, maximum, minimum, and mean temperatures, solar radiation, wet days, and vapor pressure). Martínez-Gutiérrez (2007) used 14 climatic variables (average annual temperature, mean diurnal range, seasonal temperature, annual temperature range, average temperature of wettest quarter, mean temperature of driest quarter, mean temperature of warmest quarter, mean temperature of coldest quarter, annual precipitation, seasonal rainfall (coefficient of variation), precipitation of wettest quarter, precipitation of driest quarter, precipitation of warmest quarter, and precipitation of coldest quarter) and three topographic variables (elevation, slope and topographic index). Both studies subsequently filtered suitable areas based on data on human-associated threats (e.g., roads) and other factors.

Habitat Factors Associated with Wolf Fecundity: Prey Data for Mexico

Estimates of prey abundance in Mexico are limited in spatial extent in comparison to those collected by state game agencies within the US. For this reason, the most comprehensive evaluation of potential wolf reintroduction areas in Mexico (Araiza et al. 2006) relied on expert-based estimates of prey abundance within core areas of suitable habitat. Estimates for all of the six areas were between 2 and 4 deer per km², which would correspond to densities of 10-17 wolves/1000 km² based on the model of Fuller et al. (2003). Subsequent studies (Arellano et al. 2009, Lara-Diaz 2011) using standardized survey methods have found similarly low prey densities within potential wolf habitat in northern Mexico. Another potential source of prey abundance data derives from information collected by Game Management Areas (UMA). UMA are required to base the number of hunting permits sold on estimates of prey abundance.
Although these estimates are often greater than 2-4 deer per km², the lack of standardized methodology, limited area sampled, and financial motivation to inflate estimates cause these data to be of limited relevance to recovery planning.

The diversity of prey available to Mexican wolves in ecosystems of the Sierra Madre Occidental in Mexico may be higher than in the United States, which might partially compensate for the low abundance of wild ungulates. In a prey survey in Sierra Madre Occidental, Servín et al. (2007) found that ungulates (deer) constituted 84% of total wild prey biomass (1.92 of 2.28 kg/ha), whereas small prey (rodents, rabbits, and hares) constituted approximately 16%.

Habitat Factors Associated with Wolf Survival: Available Data for Mexico

The relative proportion of private to public lands is higher in northern Mexico than in the southwestern US. Private lands make up a majority of the states of Northern Mexico (Chihuahua 84.9%, Sonora 76.8%, Coahuila 73.9%, Nuevo Leon 69.4%, Zacatecas 59.3%, Durango 54.7%), with remaining lands being held predominantly in communal (ejidal) rather than public ownership. Public lands cover less than 10% of northern Mexico. State and federal nature reserves cover approximately 4.4% of Nuevo Leon and 2.8% of Tamaulipas (Cantu et al. 2001).

Consequently, most wolves would eventually inhabit private lands in Mexico, although some of these large landholdings are well protected against trespass and deer populations are well-managed for commercial hunting operations. As a consequence, some large ranches may serve as core protected areas and might play a role in lowering the extinction risk of reintroduced populations.

Transportation infrastructure (e.g. roads) data for Mexico, as used in several studies including Carroll et al. (2005, 2006), are derived from the Inventario Nacional de Infraestructura para el Transporte (INIT), a national database created from state and local level roads data sources at 1:50,000 or coarser scales (Backhoff Pohls et al. 2000). Due to its coarse-scale source, the INIT data potentially excludes a large proportion of the unpaved roads within northern Mexico (Figure 4). To compensate for this omission in areas of Mexico that showed human-altered land cover types but no roads (at a resolution of 1 ha), Carroll et al. (2005, 2006) set minimum road
densities of 1.24 km/km² for pasture and 2.0 km/km² for other human-altered lands, based on an evaluation of road densities in similar land cover types in the US.

Population data for Mexico is typically derived from census databases at the locality scale (INEGI 2000). The locality is the finest scale of census data collected in Mexico, and thus approximately corresponds to the census block in the United States. However, locality data is available as point locations rather than the polygons used to delineate US census blocks.

Livestock data for Mexico may be derived from the Census of Agriculture at the municipality level (Census of Agriculture 1991). Because available data on human settlement patterns and roads is relatively sparse in Mexico, data on livestock density may allow more realistic evaluation of potential wolf survival in remote areas.

Potential Core Areas of Suitable Habitat in Mexico

Potential core areas of suitable habitat in Mexico are found along the mid to higher elevations of the Sierra Madre Occidental (2400-3200m), as well as in two smaller mountain ranges located in Coahuila (Maderas del Carmen) and Nuevo Leon (Sierra Plegada) (Figures 7 and 8). Due to the continuous band of forest habitat at higher elevations of the Sierra Madre Occidental, wolves historically may have been widely distributed through this region. In contrast, the Maderas del Carmen and Sierra Plegada are relatively isolated from other areas of temperate forest habitat (Araiza et al. 2006, in press) (Figures 7 and 8).

In 2006, a workshop convened researchers involved with several of the studies described above, in order to derive a consensus opinion of which areas held potential for wolf reintroduction in Mexico (Araiza et al. 2006, in press). Because these six areas have subsequently formed the focus of recovery planning in Mexico, we describe them in greater detail here. Araiza et al. (in press) subsequently analyzed habitat suitability and human-associated mortality risk within each of the six larger areas to identify optimal sites in which to focus recovery efforts. Using historical occurrence records, Araiza et al. (in press) ranked vegetation types as to suitability. The study then developed three alternate scenarios for human-associated risk (low, intermediate, and high risk) that made alternate assumptions as to the extent of the zone around roads and human settlements in which wolves would experience increased mortality. Although the expert’s
workshop (Araiza et al. 2006) had concluded that patches of suitable habitat larger than 10,000 km² were most suitable for reintroductions, no single patch in any of the six areas met that criterion (Araiza et al. in press). However, the largest clusters of suitable patches were found in Sonora-Chihuahua (area 1) and Chihuahua-Durango (area 3) (15,705 and 8,344 km² in area, respectively, under the intermediate risk assumptions; Figure 8).

The six potential reintroduction areas identified by Araiza et al. (2006, in press) generally correspond with core areas identified in the various habitat models cited above (Table 1). Many of these areas are not under legal protection, because past conservation efforts in Mexico have primarily focused on Desert and Tropical Forest biomes. The Mexican wolf conservation program thus has stimulated broader awareness by the Mexican federal government of the need to protect areas of temperate forests in northern Mexico.

**Description of six candidate core areas of suitable habitat in Mexico (numbering as shown in Table 1 and Figure 7)**

1. **Sierra San Luis and Ajos-Bavispe (Sonora/Chihuahua) Complex:** This area, of 10-15,000 km² in extent, lies in the northern portion of the states of Chihuahua and Sonora, abutting the US border and the northern end of the Sierra Madre Occidental. Vegetation ranges from lower elevation desert grassland to montane forest. The area is estimated to support 2-4 deer per km². Livestock density is approximately 5 cattle per km². In October 2011, five wolves were released in this area. Araiza et al. (2006) estimated that the area could support 80 wolves.

2. **Tutuaca and Sierra Tarahumara (Chihuahua) Complex:** This area, of 10,000 km² in extent, lies in the Sierra Madre Occidental in the central and southern portions of the state of Chihuahua. Vegetation is primarily montane pine and pine-oak forest and grassland. A protected area of the same name (Refugio de la Fauna Silvestre Tutuaca) lies within this area. The area is estimated to support 2-4 deer per km² (Araiza et al. 2006) and may range up to 6 deer per km² in some areas (J. Servín, unpubl. data). Livestock density is about 4 cattle per km². It is estimated the area could support 80 wolves (Araiza et al. 2006).
3. Chihuahua/Durango Complex: This area, of 15,000 km$^2$ in extent, lies in the central Sierra Madre Occidental on the border of the states of Chihuahua and Durango. Vegetation is montane pine, pine-oak, and oak forest and grassland. The area is estimated to support 2-4 deer per km$^2$ (Araiza et al. 2006) and may range up to 7 deer per km$^2$ in some areas (J. Servín, unpubl. data). Livestock density is about 7 cattle per km$^2$. Road density is less than 0.23 km/km$^2$. It is estimated the area could support 60 wolves (Araiza et al. 2006).

4. Sierra de Valparaiso/Sierra de Urica and Mezquital (Zacatecas/Durango) Complex: This area, of 6,000 km$^2$ in extent, lies in the southern Sierra Madre Occidental on the border of the states of Durango, San Luis Potosi and Zacatecas. Vegetation is montane pine, pine-oak, and oak forest, grasslands, and mesquite shrublands. The area is estimated to support 2-4 deer per km$^2$ (Araiza et al. 2006) and may range up to 6 deer per km$^2$ in some areas (J. Servín, unpubl. data). Livestock density is about 6 cattle per km$^2$. Road density is low at approximately 0.08 km/km$^2$. It is estimated the area could support 24 wolves (Araiza et al. 2006).

5. Maderas del Carmen and Serranias de Burro (Northern Coahuila) Complex: The area of the Sierra del Carmen in northern Coahuila, of 13,000 km$^2$ in extent, is characterized by pine-oak and oak forest, grassland and mesquite shrubland vegetation. The area is estimated to support 2-4 deer per km$^2$. Livestock density is about 6 cattle per km$^2$. Road density is less than 0.23 km/km$^2$. It is estimated the area could support 85-100 wolves (Araiza et al. 2006).

6. Sierra Plegada (Nuevo Leon/Tamaulipas) Complex: This mountain range, of 17,000 km$^2$ in extent, lies primarily in the state of Nuevo Leon. Vegetation is primarily montane pine-oak and oak forest, grassland, and mesquite shrubland, with a sub-tropical forest influence in the eastern portion of the area. The area is estimated to support 2-4 deer per km$^2$. Livestock density is about 7 cattle per km$^2$. Road density, although averaging less than 0.23 km/km$^2$, is somewhat higher than in the Sierra Madre Occidental. It is estimated the area could support 60-140 wolves (Araiza et al. 2006).

Connectivity Between Potential Core Areas of Suitable Habitat in Mexico
Araiza et al. (2006) considered all of the six areas described above as adequately connected with at least one other potential core area of suitable habitat. However, the authors noted that areas in the southern Sierra Madre Occidental (e.g., Chihuahua/Durango and Valparaiso/Mezquital) were likely to be better connected to the wolf metapopulation than were areas to the east in Coahuila and Nuevo Leon. It is difficult to quantitatively assess potential connectivity between the six areas, beyond conclusions based on the general distribution of suitable montane habitat, because of the coarse resolution of available data on mortality risk factors (e.g., roads).

Servín et al. (2007) proposed that the six Mexican core areas of suitable habitat in Mexico might form two disjunct metapopulations. The larger metapopulation would include the four areas in the Sierra Madre Occidental, with interchange of dispersers along the Sierra Madre Occidental from Sonora to Zacatecas, with potentially connections with the Blue Range Wolf Reintroduction Area in Arizona and New Mexico. The two areas in eastern Mexico (Coahuila and Nuevo Leon) could potentially exchange dispersers with Mexican wolf populations in Texas and New Mexico.

We considered the relative distance between the various Mexican core areas and with the US areas to qualitatively evaluate the connectivity between sites (Table 1). Areas in eastern Mexico (Sierra Plegada and Maderas del Carmen) are qualitatively better connected to each other than to the other 4 potential core areas in western Mexico. This is due to barriers created by large areas of unsuitable low-elevation habitat between these areas and other populations. However, higher-elevation areas may offer some potential for connectivity between the Sierra Plegada and Zacatecas/Durango potential recovery areas (J. Servín, pers. comm.). The four areas in the Sierra Madre Occidental are largely connected with each other and to a lesser degree, through the Sierra San Luis Complex, to the Blue Range core area.

Comparing potential core areas of suitable habitat in Mexico

Araiza et al. (2006) estimated potential size of wolf populations in the six core areas of suitable habitat in Mexico (Table 1). These estimates indicate that the areas have varying potential to contribute to recovery. Areas in the Sierra Madre Occidental are more likely to form part of a connected metapopulation than are the two eastern areas. Additionally, the two areas in the
northern Sierra Madre Occidental are predicted to support larger wolf populations (80 wolves each) than are the two areas in the southern Sierra Madre Occidental (60 and 24 wolves). However, the relative potential for successful reintroductions within each of these areas may also depend on public attitudes and details of land use that are not quantifiable using available data (Servín et al. 2007).

Comparing potential core areas of suitable habitat between the US and Mexico

Although we sought to use the best available data in both the US and Mexico, we encountered inconsistencies in the resolution and completeness of data between the two nations. This inconsistency was greatest for the roads data, as the mapped roads network in Mexico was quite sparse when compared to the relatively complete mapping of four-wheel drive routes in the US (INIT, USGS)(Figure 4). In contrast, human population data was relatively consistent in scale between the two nations. Carroll et al. (2005, 2006) concluded that the sparseness of the available data on mapped human impacts (roads and altered habitat types) in remote areas of the Sierra Madre Occidental strongly affected estimates of potential wolf habitat. The authors therefore concluded that their model results for the Sierra Madre Occidental should be used only as an initial comparison of habitat suitability among sites within Mexico to be followed by local surveys of land use and prey abundance.

Available vegetation data also differed between the two nations. Such data was available at a finer spatial scale in US than Mexico. Conversely, thematic detail (floristic types) was greater for the Mexican data. However, due to the generalized nature of the rankings of vegetation by wolf habitat value (both due to generalist nature of wolf habitat associations and lack of detailed data on Mexican wolf natural history) and the large extent of wolf territories, both the thematic and spatial detail of the vegetation data is sufficient for the recovery planning.

These bi-national contrasts in the data used in the studies reviewed above limit quantitative comparison of habitat suitability between US and Mexican potential core areas of suitable habitat. For example, Carroll et al. (2005) concluded that “the resolution of the habitat data was still inconsistent between US and Mexico to an extent that significantly limits comparability between Mexican and US reintroduction sites.”
Implications of comparison of core areas of suitable habitat

Despite the challenges arising from bi-national contrasts in available data, we conclude based on qualitative comparisons that potential core areas in the US are likely to support larger wolf populations than potential core areas in Mexico (Table 1). The core areas identified in the US are 24,000-25,000 km² in extent. Core areas identified by Araiza et al. (2006) in Mexico were 6,000-17,000 km² in extent. Although the subsequent analysis by Araiza et al. (in review) expanded the potential recovery areas to encompass areas of 12,000 to 30,000 km² in extent, they noted that areas of low or moderate mortality risk formed no more than half of these expanded areas (e.g., 10,500 of the total 30,000 km² comprising the Chihuahua/Durango potential recovery area).

More importantly, the contrast in prey density between the US and Mexico core areas results in a contrast in estimates of the number of wolves that could be potentially supported in each of the core areas. Ungulate biomass in US core areas (with the exception of western Texas, where prey density is likely low) was 4.1-7.6 deer equivalents (UBI)/km² vs. 2-4 deer/km² in Mexico. Although habitat exists in the in the U.S./Mexico border area, the area would likely serve as a mortality sink for wolves (Carroll et al. 2005). The Service concluded that other than the BRWRA, other reintroduction sites in the border country were isolated and could each support only 5 to 30 wolves (U.S. Fish and Wildlife Service 1996). This is consistent with Service findings that the small isolated gray wolf population that inhabits Isle Royale National Park (Peterson et al. 1998) has no relevance to gray wolf recovery in the Western Great Lakes states (U.S. Fish and Wildlife Service 1992, U.S. Fish and Wildlife Service 2011).

Recommended Recovery Region for the Mexican Wolf

Studies of Mexican wolf habitat suitability in the US and Mexico as summarized in this section indicate that the most feasible and expeditious recovery strategy will involve establishing Mexican wolf populations in a recovery region that includes Mexico, extreme western Texas, Arizona, New Mexico, southern Utah (as circumscribed by interstate highways 15 and 70), and southern Colorado (as circumscribed by interstate highways 70 and 25). Three core areas of suitable habitat exist within this recovery region and include: 1) the BRWRA and adjacent public...
lands, 2) the Grand Canyon and adjacent public lands in northern Arizona and southern Utah (circumscribed by interstate highways 15 and 70), and 3) two linked areas of public lands and private lands with conservation management in northern New Mexico and southern Colorado (circumscribed by interstate highways 70 and 25). Primary reintroduction sites could be found within each of these core areas since they all include large patches of high quality habitat on public or private lands subject to conservation mandates (National Park, wilderness, conservation easements) where wolves would probably experience relatively low human induced mortality. The uncertainty introduced by climate change notwithstanding, these core areas of suitable habitat are projected to persist under potential future landscape changes (Carroll et al. 2006). Based on GIS modeling of current habitat conditions it is estimated that three core areas in the US could support > 250 wolves (Table 1) and the entire US portion of the recovery region could support > 1,000 wolves (Carroll et al., 2003, 2006). In an independent assessment of standing ungulate biomass, Heffelfinger et al. (unpublished data) used ungulate density estimates and concluded current abundance levels in the entire US portion of the recovery region could support > 900 wolves.

Relevance to Historical Range

Two of the core areas (i.e., the Grand Canyon and northern Arizona/southern Utah core area and the northern New Mexico/southern Colorado core area) are located north of the Mexican wolf’s historical range. For several reasons it is appropriate to include both in the Mexican wolf recovery area.

Mexican Wolf is a Close Living Relative to the Gray Wolf Subspecies That Occupied the Areas Historically

The Mexican wolf is a close living relative to the gray wolf subspecies that occupied the areas historically. These two core areas are proximate to (Brown 1983, Bogan and Mehlhop 1983, Hoffmeister 1986, Nowak 1995) or well within (Leonard et al. 2005) the zone of gray wolf genetic intergradation that characterized the southwest historically (see Taxonomy). Leonard et al. (2005) interpret the geographic distribution of genetic markers as evidence that historical gene flow among the Mexican wolf and other wolf “subspecies” was extensive in time and space and
supports an area for recovery of the Mexican wolf that extends well beyond the subspecies historical range.

The Mexican Wolf is the Closest Geographic Source of Wolves

The Minnesota wolf (*C. l. nubilus*), a close relative of the Mexican wolf, was probably widespread throughout the southwestern US historically (Nowak 1995) until it was extirpated from the region over 50 years ago (Brown 1983, Robinson 2005). In response, at least a few Mexican wolves moved north to occupy the vacated habitat in New Mexico and Arizona (Gish 1977, Scudday 1977, Nowak 1995). Nowak (1986:1-2) considered the relevance of shifting ranges when he endorsed the reintroduction of the Mexican wolf “beyond its designated range on the grounds that it could have occupied such sites naturally, if other wolves had not already been there, and indeed, may have been attempting to do so after the other wolves had been extirpated...

... Suppose, however, that there had been no gray wolves to the immediate north of the range of bailey. In that case, there is no reason to think that baileyi would not have kept right on going to eventually occupy a large part of the western United States... The genus *Canis* is remarkably adaptable to a variety of conditions. The main factor limiting the distribution of a particular species or subspecies seems not to be different habitat conditions, but rather the presence of another kind of *Canis*. It has not been unusual for one subspecies of gray wolf to invade and establish itself in the range of another subspecies that had disappeared.”

Wide-ranging wolves from the BRWRA affirm Nowak’s expectation about range expansion and indicate that the subspecies’ current range extends north of the historical range proposed by Parsons (1996). Two wolves from the BRWR traveled to the edge of the historical range and two beyond that range (see Life History). The wolf’s ability to colonize distant, unoccupied habitat is well known (Mech and Boitani 2003) and is one reason why the USFWS recognizes the importance of long distance movements by gray wolves for defining the boundaries of recovery areas (U.S. Fish and Wildlife Service 2009:15126 – 15127). It is quite possible that the four wolves that traveled considerable distances from the BRWRA could have survived and reproduced (assuming the presence of other Mexican wolves) in areas well outside the historical range if they had not been captured and returned to the BRWRA. The proximity of the BRWRA population increases the likelihood that northern Arizona/southern Utah and northern New...
Mexico/southern Colorado the area will be part of the subspecies future range due to similar forays by other young dispersing wolves.

Mexican Wolf is Capable of Living as Far North as Southern Utah and Southern Colorado
(see Wolves and Prey).

Mexican Wolf in Greatest Need of Conservation Assistance

As noted previously (see Taxonomy and Distribution) early taxonomists identified five gray wolf subspecies that inhabited the southwestern US including three (C. l. mogollonensis, C. l. monstrabilis, C. l. youngi) that have been have been extinct for decades and a fourth (C. l. nubilus) that is represented in the wild by a robust population in the western Great Lakes states and eastern Canada. This subspecies was extirpated from the southwestern US over 50 years ago (Brown 1983, Robinson 2005). The fifth southwestern subspecies, C. l. baileyi, is represented in the wild by only one small population in the BRWRA (see Current Population and Trends). Given its precarious status in the wild, the Mexican wolf is the most endangered gray wolf subspecies (Phillips et al. 2000) and has been targeted as a conservation priority by the Wolf Specialist Group for the International Union for the Conservation of Nature (IUCN) (L.D. Mech, pers. comm.). Including northern Arizona/southern Utah and northern New Mexico/southern Colorado in the Mexican wolf recovery area is strongly indicated from a conservation perspective.

Including Areas in Recovery That Are Located Outside the Historical Range for the Mexican Wolf is Consistent With the Best Available Science

Defining a Mexican wolf recovery area that extends outside the historical range for the subspecies is consistent with the conclusion reached by the IUCN Conservation Breeding Specialist Group and other experts involved in a comprehensive wolf population and habitat viability analysis (Phillips et al. 2000). Additionally, it is consistent with the findings of the science and planning subgroup of the recovery team that was assembled to develop a recovery plan for the gray wolf southwestern distinct population segment (DPS) that was adopted by the USFWS in 2003 and included the southern half of Utah and Colorado (Federal Register 68:15804 – 15875). Members of that subgroup concluded that C. l. baileyi was the most
appropriate source stock for recovering the DPS (U.S. Fish and Wildlife Service 2003).

More broadly, defining a recovery area that extends outside a species or subspecies historical range following a comprehensive assessment of historical, contemporary, and future conditions is supported by leading ecological research (Lomolino 2006, Caro 2007, McLachlan et al. 2007, Davis et al. 2011).

In an increasingly dynamic and uncertain world (Dimento and Doughman 2007, Brown 2011, Orr 2010), recovering taxa outside purported historical ranges based on diligently assembled scholarship from the best available science is often times justified (Lomolino 2006, Caro 2007, Hunter 2007, McLachlan et al. 2007, Hayward 2008, Davis et al. 2011, Marris 2011). This will likely be especially true for species that are defined by ecologically similar subspecies with historical distributions that included extensive zones of intergradation. Such an approach to recovery will allow such species (or subspecies) to experience greater security than a more conservative approach based on an exclusive focus on subspecies’ historical ranges. The Mexican wolf is such subspecies: it arises from a species that is defined by many subspecies all of which were ecological generalists with historical ranges that included wide zones of ecologic and genetic integration (Brewster and Fritts 1995, Mech and Boitani 2003:11 17, Von Holdt et al. 2011, Chambers et al. submitted).

Due to alteration of the historic habitat inhabited by Mexican wolves from human development and resource use, defining a recovery area for the Mexican wolf that focused solely on historical range would preclude recovery. The authors of the 1982 Mexican Wolf Recovery Plan commented: “In formulating a recovery plan objective for any subspecies of C. lupus, one must realistically view, not only the causes of the wolf’s past endangerment, but also present trends toward ever-increasing human needs – whether real or perceived – for space and for the renewable and nonrenewable resources present or producible in wolf habitat” (USFWS 1982:23). The tension between the recovery effort and habitat availability within historical range led them to conclude that recovery of the Mexican wolf was not possible. This problem is remedied by including areas outside the Mexican wolf’s historic range in the recovery area.

Land Ownership Status and Use in the US and Mexico
Recovery plans in the United States for wide-ranging species such as the wolf typically assume that the primary responsibility for species conservation will fall on federal lands, with additional activities potentially occurring on private and other non-federal lands when these actions are also necessary for recovery. A mixed pattern of land ownership characterizes the Mexican wolf recovery area in Utah, New Mexico, and Arizona (Figure 9, Table 3). In contrast, western Texas is nearly all privately owned which seriously compromising the usefulness of otherwise suitable wolf habitat there to serve as a primary reintroduction area. Regulations limiting wolf mortality in western Texas (e.g., limitations on hunting of wolves) could, however, allow a population of wolves to become established there due to natural dispersal from either the Blue Range or any wolf populations resulting from future reintroductions in the northern portion of Coahuila state (Mexico).

Table 3*. Land ownership in the Mexican wolf recovery area.

<table>
<thead>
<tr>
<th>Category of Land Type (Landownership)</th>
<th>Amount of land type found within the Proposed Contemporary Mexican Wolf Range in U.S. (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal Land</td>
<td>36.6%</td>
</tr>
<tr>
<td>Native American Land</td>
<td>12.8%</td>
</tr>
<tr>
<td>Private Land</td>
<td>41.7%</td>
</tr>
<tr>
<td>State Land</td>
<td>8.6%</td>
</tr>
<tr>
<td>Other Land (Local Govt. Unknown, Joint Ownership)</td>
<td>.3%</td>
</tr>
</tbody>
</table>

*Note: We are still waiting on data layers to be able to map/calculate land ownership for Mexico.

Mexico

Ejidos and communities

Policy-Related Considerations

ESA

An exclusive focus on historical range is not mandated in the ESA or related USFWS policies.
There is no direct reference to historical range in the ESA, and only one ESA related policy makes reference to it [50 CFR 17.81(a)]: “The Secretary may designate as an experimental population a population of endangered or threatened species that has been or will be released into suitable natural habitat outside the species current range (but within its probable historic range)…” But even here the USFWS Director has discretion based on current conditions [50 CFR 17.81(a)]: “… an experimental population can be established outside a species historic range if the Director finds that the primary habitat of the species has been unsuitably or irreversibly altered or destroyed.” The best available science (see Geography of Recovery) indicates that because of a lack of suitable habitat Mexican wolf recovery cannot be achieved unless the recovery region includes areas outside the subspecies historical range.

USFWS has supported endangered species recovery efforts in regions that were not necessarily considered historical habitat including black-footed ferret (Mustela nigripes) conservation efforts near Janos, Mexico (Anderson et al. 1986, http://www.fws.gov/mountainprairie/species/mammals/blackfootedferret/archives.htm); California condor (Gymnogyps californianus) reintroductions in northern Arizona (Mesta 1996, USFWS 1996, Snyder and Snyder 2000, USFWS 2012); westslope cutthroat trout (Oncorhynchus clarki lewisi) conservation efforts in southwestern Montana (USFWS 2007); and gray wolf recovery efforts in the Greater Yellowstone Ecosystem (Fritts et al. 1997). Since the Minnesota gray wolf (Canis lupus nubilus) seemingly occupied the GYE historically, rather than the Alaskan gray wolf (Canis lupus occidentalis) from Alberta and British Columbia, Canada (Nowak 1995), the former could have been used for reintroductions rather than the latter which was used because the animals were familiar with the habitats and prey (Fritts et al. 1997).

The Mexican wolf recovery region recommend in this plan is similar to the area delineated for southwestern gray wolf distinct population segment (DPS) that was adopted by the USFWS in 2003 (Federal Register 68:15804 – 15875). The science and planning subgroup of the team that was assembled to develop a recovery plan for the DPS concluded that C. l. baileyi was the most appropriate source stock for recovering the DPS (USFWS 2003).
Describe state game commissions, state laws/regulations/commission policies/rules, management plans, etc. related to wolves.

Binational US-Mexico Policy Coordination

As previously described (see Background), Mexico and the United States have worked independently yet collaboratively on Mexican wolf recovery for over three decades. Today, both countries are actively engaged in the binational captive breeding program and in efforts to re-establish the Mexican wolf in the wild. Recognition of the historical cross-border distribution of the Mexican wolf paired with recognition that the two countries’ legal frameworks for species protection differ, leads both countries to desire the establishment of a bi-national collaborative framework that is mutually supportive yet respectful of each country’s autonomy.

Smaller populations in Mexico as well as in the US (e.g., Texas) could be critically important for ensuring connectivity between larger core areas, as well as meeting representation goals. The potential for connectivity between US and Mexican wolf populations suggests that recovery planning would benefit from a binational coordination. However, determining the appropriate degree of coordination, and the respective roles of actions in US and Mexico, is difficult given contrasting policy and biological contexts in the two nations.

There are many similarities between Mexico and the United States in the regulatory context of Mexican wolf conservation. Both have federal legal frameworks for recovery: Mexico's Ley General de Vida Silvestre (2000), NOM 059 ECOL 2001 (2002), and the United States' ESA ofBoth nations have developed recovery plans for the Mexican wolf. Mexico's Programa de Recuperacion del Lobo Mexicano was published in 1999; the United States' Mexican Wolf Recovery Plan was published in 1982, and was co-signed by Mexico's Direcccion General de la Fauna Silvestre. In both nations, Federal agencies lead the recovery efforts: Mexico's Direcccion General de Vida Silvestre (DGVS) and the US Fish and Wildlife Service (FWS). Both nations have comparable advisory committees for recovery: Mexico's Subcomite Technico Consultivo Nacional para la Recuperacion del Lobo Mexicano (STCN RLM); the United States' Mexican Wolf Recovery Team. In both nations, the parties interested in and affected by wolf recovery
actions include state and local governments, as well as non-governmental organizations and private property owners.

There are, however, also significant differences in the regulatory context between Mexico and the United States. Whereas the US ESA mandates development of species-specific recovery criteria, Mexico's red list of endangered species (NOM 059 ECOL 200 1) has downlisting criteria that apply to broad categories of species, one of which includes the Mexican wolf.

Local and Regional Culture

Etc...

Summary Description of Recovery Area
J. **Reasons for Listing/Threats Assessment**

(Note to Reviewer: I have provided an explanation of what this subsection of the plan should provide directly from the Service’s recovery planning guidance: “This subsection should include an overview of the species’ decline, and its causes of decline (to the extent they can be determined). The causes of decline, or threats, may be past, continuing from the past into the future, newly identified, and reasonably anticipated in the future (including, but not limited to, those that have been temporarily curtailed but are likely to recur). Where possible, this subsection should also identify the source of threats, e.g., if the threat is siltation in a stream, the source could be urban runoff, watering cattle, removal of riparian vegetation, recreational uses, etc. Noting the source helps tailor the recovery action(s) needed. When discussing each threat and its source(s), the geographic scope, severity, and frequency of the various threats should be indicated, noting those that present greater or lesser threats to the species.

Uncertainties with respect to threats to the species should be identified as well…To provide continuity among the listing package, this section and the recovery criteria, threats that were listed in the final rule should be addressed in this section and discussed in terms of the five listing factors. If the species was recently listed, much of this information can be taken from the “Factors Affecting the Species” section of the listing rule. Plans should assess any new threats, changes in severity of threats, and threats that have been reduced or removed since publication of the final listing rule.)”

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). A species is listed as threatened or endangered if one or more of the following five factors in section 4(a)(1) of the ESA are determined to be responsible for its condition (a process referred to as a 5-factor analysis):

(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 while a species is listed to periodically 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 conducted a 5-factor analysis of 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 reintroduction 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 interactions would increase as the number of wolves increased.

The Mexican Wolf Conservation Assessment (USFWS 2010 add cite) contained an updated 5-factor analysis specific to the Blue Range population (…summarize findings…). The draft reclassification…. The following 5-factor analysis identifies current and anticipated threats throughout the entire area considered potentially suitable recovery habitat for the Mexican wolf (see Geography of Recovery), thus the geographic scope of this assessment is larger than that in the Conservation Assessment or the draft rule to reclassify…. When available, information on the source, geographic scope, severity, frequency, and overall known or perceived magnitude of each threat is provided.
(This table is a result of team brainstorm at February 2012 meeting; we will continue to revise it…)

<table>
<thead>
<tr>
<th>Factor A: Habitat Attribute</th>
<th>Stressor</th>
<th>Geographic Scope</th>
<th>Severity / Intensity</th>
<th>Occurrence (Past/present/future; single episode vs. continuous; regular vs. sporadic; likelihood)</th>
<th>Overall Magnitude</th>
<th>Response</th>
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<tbody>
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<td>Prey Availability / Biomass</td>
<td>Forage production</td>
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<td>Competition between livestock and other prey for forage</td>
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<td>Spread of non-native vegetation (inedible? lower nutrition?)</td>
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<td>Ungulate mortality</td>
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<td>Ungulate Disease (See Factor C.)</td>
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<td>Ungulate mortality; ___ in wolves</td>
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<td>Increasing urbanization</td>
<td>Decreased ability for natural wolf range expansion; decreasing habitat availability over time in areas of low human inhabitance; increased likelihood of wolf-human interactions</td>
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<tr>
<td>Increasing road density / traffic</td>
<td>Mortality from vehicular collision; behavior modification? (denning, dispersal)</td>
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<td>Quantity of public land</td>
<td>Private lands have a greater potential for human-wolf interactions</td>
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<td>Wildfire</td>
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<td>Habitat Connectivity to Support Migration Between Subpopulations</td>
<td>Mortality? Prey availability?</td>
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<td>Regional Drought Cycles</td>
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<td>Mortality from vehicular collision during dispersal events; no genetic exchange between subpopulations</td>
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<td>Factor B. Overutilization</td>
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<td>Incidental take by FWS and partner agencies</td>
<td>Vaccinations and medical treatment; capture and control actions</td>
<td>Mortality</td>
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<td>Factor C. Disease</td>
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<td>Rabies</td>
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<td>Transmission by domestic canids</td>
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<td>Transmission by wild canids or other animals</td>
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<td>Mortality</td>
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<td>Lack of labeled vaccines for wolves</td>
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<td>Parvovirus</td>
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<td>Corona virus</td>
<td>Chronic wasting disease</td>
<td>Mortality to ungulates;</td>
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<td>Predation (on wolf by other predators)</td>
<td>Competition between predators</td>
<td>Mortality</td>
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<td><strong>Factor D. Regulatory Mechanisms</strong></td>
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<td>Legislative efforts to delist wolves in UT, AZ, NM</td>
<td>public opinion</td>
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<td>Illegal / accidental take of Mexican wolves</td>
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<td>McKittrick policy / difficulty successfully prosecuting offenders</td>
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<td>Nighttime spotlight hunting</td>
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<td>Misidentification</td>
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<td>Lack of law enforcement capacity</td>
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<tr>
<td>Progress / status of BRWRA</td>
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| reintroduction | BRWRA Regulations  
|                | BRWRA boundary,  
|                | SRZ/PRZ. Removals  
|                | due to depredations,  
|                | boundary removals,  
|                | etc. |
| Funding mechanisms to support reintroduction and recovery |  |
| Mechanisms to regulate hybrids | Competing management regimes  
|                | stemming from single species management focus (e.g., MSO vs MW?) |
| Mechanisms that reduce forage (repetitive with factor A?) |  |
| Insufficient 7(a)(1)(A) | Budgetary and staffing constraints of federal agencies |
| Management by litigation | Public opinion; lack of policy direction from USFWS (SPR, use of DPS policy, etc). |
| Lack of a (binational) | FWS priorities, US-Mexico coordination |
### Recovery Plan

<table>
<thead>
<tr>
<th>Factor E. Other</th>
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<tbody>
<tr>
<td>Tribal participation in recovery</td>
<td>Lack of funding, economic impacts</td>
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<td>Competing land uses</td>
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<td>Cultural values</td>
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<td>Stakeholder participation in recovery</td>
<td>Inadequate public education</td>
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<td>Social and economic impacts</td>
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<td>USFWS intolerance of local communities, culture</td>
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<td>Lack of funding to support recovery implementation</td>
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<td>Interagency coordination to support recovery</td>
<td>Political support</td>
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<td>Foothold traps</td>
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<td>Human tolerance</td>
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<td>Release sites too close to human inhabitance</td>
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<td>Fear of wolves, negative perceptions of wolves</td>
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<td>Dislike of federal government</td>
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<td>Economic impacts of reintroduction</td>
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<td>Wolf habituation to humans</td>
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<td>Progress of BRWRA</td>
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<tr>
<td>Lack of response to 3 year and 5 reviews</td>
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<td>Depredation and boundary related removals</td>
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<td>Human-caused mortality (all sources; poisoning, road kill, other)</td>
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<tr>
<td>Lack of incentives, funding, resources to support implementation, esp. in local communities to reduce interactions,</td>
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<tr>
<td>Genetic health</td>
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<tr>
<td>Lack of gene flow</td>
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<td>Hybridization with dogs and coyotes</td>
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<td>Genetic swamping by northern wolves</td>
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<td>Low levels of genetic variation, lack of robustness</td>
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<tr>
<td>Limited capacity of captive breeding program</td>
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Use of livestock protection collars

especially depredation; management of human habituated wolves, aversive conditioning

communication with affected parties

monitoring of uncollared wolves

Lack of trust (of USFWS) due to failure to live up to commitments
K. Conservation Efforts

(Note to Reviewer: This section is not intended to be a laundry list of all conservation efforts, rather it is a concise list of those efforts that most contribute to recovery. Due to the specific situation with the Mexican wolf, i.e., that it is contained within the BRWRA, I’m not sure this section is terribly relevant. We may just want to reiterate the reintroduction projects and captive breeding program with some mention of important partners, etc. Perhaps also the Interdiction Council?)
L. **Biological Constraints and Needs**

(Note to Reviewer: Recovery planning guidance says, “Based on all of the above, identify any biological constraints or needs of the species that need to be considered in planning and management. The purpose of this section is to state up front any known limiting factors that are biologically inherent in the species and non-modifiable, and which *must be honored* when designing any management/recovery program for that species. Examples might include extremely delayed maturity which requires unusually high annual survival in juvenile stages; needs for a particular and rare habitat for one or another life history stage; or a need for a minimum population size for successful breeding behavior.”)

Perhaps we focus here on the “basic three”, prey, large area, and security from humans? Whatever constraints we list, this section will not provide new information; rather it will refer back to where the constraints are initially discussed (probably in the Background or Threats Assessment) and reemphasize them as critical considerations for the recovery effort. This section should be just a few pages or less in length. )

**Large Area with Security from Human Exploitation**

**Prey**

Historical data indicate that Mexican wolves preyed extensively on the diminutive Coues white tailed deer (*Odocoileus virginianus couesi*) prompting some to suggest that the subspecies was an ecological or habitat specialist (Brown 1983:6 12). An early assessment of Mexican wolf ecology was completed by McBride (1980). On the notion that the Mexican wolf was a habitat specialist fine tuned to the Madrean montane forests, evergreen woodlands, and adjacent grasslands in Mexico, extreme southeast Arizona, and southwest New Mexico (Brown 1983:7), McBride (1980:13) wrote: "While it might appear that wolves are attracted to certain vegetative associations, they are actually responding to the
Historically Mexican wolves in Mexico probably preyed differentially on Coues white tailed deer simply because of its relative abundance. Supporting this notion are studies that indicate that elk (*Cervus elaphus*), the most abundant wild ungulate in the BRWRA, is the primary prey of Mexican wolves there despite an abundance of mule deer (*Odocoileus hemionus*) and white-tailed deer (*Odocoileus virginianus*) (Reed et al. 2006, Carrera et al. 2008, Merkle et al. 2009a). Consequently, the Mexican wolf recovery plan is based on the expectation that Mexican wolves can successfully subsist on both small and large ungulates.
M. Tribal Perspectives on Mexican Wolf Recovery
N. Binational Coordination for Mexican Wolf Recovery

(Note to Reviewer: The 3 paragraphs below were developed by the 2002 DPS team; perhaps they can serve as a model for us? Also, Carlos has drafted some text that for now I placed in Section III Recovery Actions as a placeholder to develop a US-Mexico MOU.)

“Despite their independent authorities, the two countries are similar in many ways regarding gray wolf conservation. Both have legal frameworks for recovery: Mexico’s Ley General de Vida Silvestre (2000), NOM-059-ECOL-2001 (2002) and the Endangered Species Act of 1983. Both countries have developed recovery plans for the Mexican wolf – Mexico’s Programa de Recuperacion del Lobo Mexicano was published in 1999; the United States’ Mexican Wolf Recovery Plan was published in 1982, and was co-signed by Mexico’s Dirección General de Vida de la Fauna Silvestre. In both countries, Federal agencies lead the recovery efforts: Mexico’s Dirección General de Vida Silvestre (DGVS) and the U.S. Fish and Wildlife Service. Both countries have comparable advisory committees for recovery: Mexico’s Subcomité Tecnico Consultivo Nacional para la Recuperacion del Lobo Mexicano (STCN-RLM); the Service’s Mexican wolf recovery team. In both countries, the parties interested in and affected by wolf recovery actions include State and local governments, as well as nongovernmental organizations and private property owners.

There are, however, significant differences between Mexico and the United States in approaches and limitations to Mexican wolf recovery. The listed entity in Mexico is the subspecies, *Canis lupus baileyi*; it is listed as extinct in the wild. In the United States, the gray wolf species, *Canis lupus*, is listed [UPDATE as necessary], with a suggested focus on the subspecies. Mexico’s red list of endangered species (NOM-059-ECOL-2001) has down-listing criteria that apply to broad categories of species, one of which includes the Mexican wolf. The United States’ recovery plan does not include downlisting or delisting criteria [UPDATE!]. Once a Federal recovery plan has been approved, Mexico has fewer legal mechanisms by which non-federal entities can constrain or advocate implementation of recovery actions than does the United States.
Clearly, the SWDPS Recovery Plan, when approved, will have legal standing in guiding recovery actions in the United States. It may also provide recommendations useful to recovery efforts in Mexico. Thus, the recovery plan can be an invaluable resource for complementary efforts in Mexico. However, Mexico is singularly responsible for enacting and implementing recovery regulations, plans, and approaches in Mexico. Its authorities and decisions are not subject to U.S. approval. Conversely, the recovery program in Mexico in terms of law, policy, and activity may provide insights for and be useful to complementary efforts in the United States, but decision made by Mexico for Mexico are not binding on the United States. Also, by necessity and force of law, each country must respect the other’s independent authority for law enforcement, i.e., Mexico cannot address law enforcement within the MOU proposed below” (excerpted from a white paper drafted by members of the 2003 SWDPS recovery team)

The US Mexican Wolf Recovery Plan will inform recovery actions in the United States. While it may also provide recommendations useful to recovery efforts in Mexico, each nation is singularly responsible for enacting and implementing recovery regulations, plans, and approaches in Mexico. Neither can extend authorities and decisions to the other. The recovery program in Mexico, in terms of law, policy, and activity, may provide insights for and be useful to complementary efforts in the United States, but decisions made by Mexico are not binding on the United States. Also, by necessity and force of law, each nation must respect the other's independent authority for law enforcement, i.e., Mexico cannot address law enforcement within a MOU with US counterparts.
II. RECOVERY STRATEGY, GOALS, OBJECTIVES, AND CRITERIA

A. Recovery Strategy

The ultimate goal of this Recovery Plan is to recover the Mexican wolf so that protections afforded by the ESA are no longer necessary, allowing delisting. The objectives of the Recovery Plan describe a scenario in which the Mexican wolf’s population is stable or increasing, well-distributed, and affected by manageable threats. This Recovery Plan was developed using the best scientific information available and a “step-down” approach of objectives, criteria and actions. As part of this approach, we have developed a state-of-the-science modeling framework that can provide information for numerous Mexican wolf recovery actions and management decisions. This modeling effort is described in detail in Appendix [].

Recovery objectives are broad statements that describe the conditions under which the Service would consider the Mexican wolf to be recovered. Recovery criteria serve as objective, measurable guidelines to assist in determining when an endangered species has recovered to the point that it may be downlisted to threatened, or that the protections afforded by the ESA are no longer necessary and the species may be delisted. Recovery actions are the Service’s recommendations to guide the activities needed to accomplish the recovery criteria. Recovery actions are designed to address the specific threats identified in this Recovery Plan. Implementation of the full suite of recovery actions will involve participation from the States, Federal agencies, non-federal landowners and the public.

The Mexican wolf represents a genetically unique lineage of gray wolf and receives specific recovery effort within the gray wolf recovery efforts of FWS. The geographical relationships of the various gray wolf genetic lineages have been dynamic over time. Rather than attempt to recreate historical abundance and distribution patterns, the primary focus of the recovery strategy is to establish wild, self-sustaining populations of Mexican wolves which will show population attributes contributing to resilience that
occurred historically and that, when achieved, demonstrate that threats have been ameliorated.

Currently, the most important biological threats to the Mexican wolf are 1) excessive mortality due to human-associated factors, 2) small population size due the existence of a single wild population with a low rate of population growth, and 3) continuing loss of genetic diversity in both the captive and wild populations.

To address these threats, this recovery strategy includes four basic steps:
1. Manage the captive population to produce reintroduction stock with an optimal genetic composition;
2. Mitigate mortality factors for the existing wild population;
3. Increase human tolerance of wolves;
4. Establish multiple wild populations of sufficient size in areas where mortality factors can be maintained at levels low enough to allow population growth, in order to minimize further loss of genetic diversity;
4. Maintain habitat connectivity to ensure that these populations are effectively connected by dispersing wolves.

These four steps are described in detail below.

B. Recovery Goals, Objectives and Criteria

1. Recovery Goal

The goal of the Mexican wolf Recovery Plan is to improve the status of the species so it can be removed from protection under the ESA. The interim goal is to downlist the Mexican wolf to threatened.

2. Recovery Objectives

The objectives of this Recovery Plan are:
1. Mexican wolf populations are sufficiently large and distributed such that the species no longer requires listing under the ESA; and

2. The effects of threats have been reduced or eliminated such that Mexican wolf populations are stable or increasing and Mexican wolves are unlikely to become threatened again in the foreseeable future.

3. Recovery Criteria

There are five Recovery Criteria in this Recovery Plan. Recovery criteria are achievable goals that we believe will result from implementation of the recovery actions in this Recovery Plan. Recovery criteria serve as objective, measurable guidelines to assist in determining when an endangered species has recovered to the point that it may be downlisted to threatened, or that the protections afforded by the ESA are no longer necessary and the species may be delisted. Achievement of these criteria will take time and is intended to be measured over the life of the plan, not on a short-term basis and should not be considered near-term recommendations. Not all recovery actions necessarily need to be implemented for the Service to consider initiating the delisting process based on the statutory criteria for determining whether a species should be listed (16 U.S.C. § 1533(a)(1)). A change in status (downlisting or delisting) requires a separate rule-making process based on an analysis of the same five factors (referred to as the listing factors) considered in the listing of a species, as described in section 4(a)(1) of the ESA. These include:

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; and
E. Other natural or manmade factors affecting its continued existence.
Recovery criteria in this Recovery Plan represent our best assessment of the conditions that may result in a determination that delisting the Mexican wolf is warranted, which we would follow by a formal regulatory rule-making process to delist the species. Recovery actions are the Service’s recommendations to guide the activities needed to accomplish the recovery criteria. Ultimately, a positive response by Mexican wolf populations to the recovery actions will mean recovery is occurring. Such a positive response will be measured in accordance with the population-related recovery criteria.

### 3.1 Reclassification to Threatened

The Mexican wolf will be reclassified to threatened when:

**Recovery Criterion 1 - Adequate population size**: Three populations, each with a census population of at least 100 individuals, had been maintained in the wild for 2 successive generations (8 years).

**Recovery Criterion 2 – Stable or Increasing Population Trend**: The overall population trend of Mexican wolves is stable or increasing over 8 years, as measured by a statistically reliable monitoring effort.

**Recovery Criterion 3 – Amelioration of human-caused mortality**: The estimated rate of human-caused losses during an 8 year period, as measured by a statistically reliable monitoring effort, is less than 17%.

### 3.2 Delisting

The Mexican wolf will be delisted when:

**Recovery Criterion 1 – Adequate Population Size:**
Option 1: A metapopulation of at least 850 individuals containing a minimum of 4 populations in the wild, that have persisted for 2 successive generations (8 successive years) at or above the following sizes: three primary core populations each with a census population of at least 200 individuals, and a total population size of at least 750, and a secondary core population with a census population of at least 100 individuals.

Option 2: A metapopulation of at least 750 individuals containing a minimum of 3 primary core populations in the wild, that have persisted for 2 successive generations (8 successive years) with a census population of at least 200 individuals each. Individuals in excess of the number required for the 3 primary core populations to reach the size stated above may occur as part of any of the 3 primary core populations.

Option 3: A metapopulation of at least 750 individuals containing a minimum of 3 primary core populations in the wild, that have persisted for 2 successive generations (8 successive years) with a census population of at least 250 individuals each.

Recovery Criterion 2 – Adequate Population Connectivity: Immigration into each of the 3 primary core populations via natural dispersal at a rate not less than 0.5 genetically effective migrants per generation, averaged over a period of 2 successive generations (8 successive years), as measured by a statistically reliable monitoring effort. If the metapopulation as a whole is equal to or greater than 850 individuals in size, immigration into one of the three primary core populations may be less than 0.5 genetically effective migrants per generation.

Recovery Criterion 3 – Stable Population Trend: The overall population trend of Mexican wolves throughout the range is stable or increasing over 8 years, as measured by a statistically reliable monitoring effort.

Recovery Criterion 4 – Post-delisting Monitoring: To monitor the continued stability of the recovered Mexican wolf, a post-delisting monitoring plan has been developed and is ready for
implementation within the States of Arizona, Colorado, New Mexico, and Utah, as required in section 4(g)(1) of the ESA.

Recovery Criterion 5 - Regulatory mechanisms: State management plans and adequate post-delisting regulatory protection are available.

* A "population" is defined as a group of wolf packs that are relatively spatially contiguous and demographically connected by dispersal events, and are relatively spatially and demographically disjunct from other groups of individuals, except for occasional dispersal events as specified above. Based on the habitat analysis presented in this recovery plan, it is anticipated that the 3 primary core populations will be located in the United States.

3.3 Justification for Recovery Criteria

This section explains the rationale for why the recovery criteria stated above are appropriate for the conservation of the Mexican wolf.

Guiding Principles for Mexican Wolf Recovery

To identify appropriate criteria for recovery of the Mexican wolf, the Service used four Biological Indicators (abundance, redundancy, connectivity, and trend) and six “Guiding Principles” to help ensure recovery of Mexican wolf.

Four Biological Indicators

1. Abundance
2. Redundancy
3. Connectivity
4. Trend
Six Guiding Principles:

1. Ensure sufficient abundance and trend indices to support population viability;
2. Ensure sufficient redundancy in populations;
3. Ensure sufficient connectivity among populations;
4. Ensure distribution of populations across representative habitats;
5. Consider and accommodate uncertainty arising from climate change, disease, environmental stochasticity, and other factors;

Rationale for Delisting Criteria

Four types of threats to species and population viability have been identified: genetic stochasticity (consisting of both inbreeding and genetic drift), demographic stochasticity, environmental stochasticity, and catastrophes (disease outbreaks, etc.). Loss of genetic variation is an inevitable consequence of finite population size. If smaller populations are connected by immigration, the genetic variation maintained by these populations approaches that of one population as large as the sum of the connected populations. Thus, sufficient connectivity among populations can help maintain genetic variation and long-term viability. Genetic threats are greater for the Mexican wolf than for other wolf subspecies because a low number of founder individuals were the source of all wolves in both the captive and wild populations. Effects of demographic and environmental stochasticity on population viability also generally diminish as the size and connectivity of populations within a metapopulation increases.
Loss of genetic variation (e.g., due to population bottlenecks) is a function of both small population size and the length of time which a population remains at small size. Thus recovery criteria and associated recovery actions that are projected to result in rapid population growth and expeditious recovery are prefereable to those that would require more time to achieve recovery. For example, an area that could potentially support a primary or secondary core population under current habitat conditions would support more expeditious recovery than would an area that would require several decades of habitat restoration before reintroductions could occur.

Variation in environmental conditions (drought, fire, prey fluctuations) and episodic threats (disease) are characteristic of wild populations of most species, including wolves. In the case of the Mexican wolf, these episodic threats interact with genetic threats. If a wolf population experienced no variation in disease occurrence or environmental conditions, a small population might better withstand genetic threats. Conversely, if the wolf population was genetically robust, then it would have the resilience to recover more easily from episodic threats. To achieve the same level of resiliency, a population derived from inbred and interrelated founders must be larger than a population derived from outbred and unrelated individuals, in order to avoid the genetic damage that occurs in a small inbred population during demographic downturns associated with episodic threats.

We used the 3-stage modeling framework to evaluate what population abundance and connectivity are necessary to withstand the threats described above. The numeric criteria detailed below are appropriate because consideration of these threats suggest that at least this number and configuration of wolves is necessary to make the listed entity no longer fit the Endangered Species Act’s definition of threatened or endangered. Recovery of smaller populations would not only be less effective in mitigating threats within each population, but would also result in a metapopulation with lower levels of connectivity. The several components of the recovery criteria are thus interrelated and mutually supporting in ensuring effective recovery of the Mexican wolf.

**Recovery Criterion 1 – Adequate Population Size.** A metapopulation size of 750 individuals, containing three primary core populations of 200-300 individuals each, is
considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity (see Modeling Appendix). Primary core populations of this size, when connected within a metapopulation, are resistant to threats to viability arising from loss of genetic variation. Three primary core populations are designated because 1) this number allows a metapopulation of sufficient size and maximizes redundancy given the configuration of suitable habitat; and 2) arrangement of the three populations facilitates natural dispersal among populations and thus retention of genetic variability. Any secondary core population(s) help ensure distribution of populations across representative habitats. Because of their smaller size, they may require dispersal from primary core populations for their persistence.

Underlying these conclusions are several themes emerging from the results of the 3 step modeling framework (see Modeling Appendix):

1) Multiple large primary core populations are likely necessary for Mexican wolf recovery
2) Smaller secondary core populations, with the possible exception of the Sonora-Sky Island population, will likely contribute minimally to sustaining a viable regional wolf metapopulation.
3) Due to its poor genetic composition, the Blue Range population (BRP) in isolation underperforms the other two primary core populations. However, when three primary core populations are present, the BRP’s central location allows it to receive dispersal from the two other populations, making its performance comparable to theirs.

The criterion for metapopulation size (750) is larger than the numeric recovery criterion for the Northern Rocky Mountains (300) and smaller than that for wolves in the Great Lakes states (1,650). The extent of genetic threats to Mexican wolves make recovery for this subspecies qualitatively different than for recovery of a metapopulation from outbred, unrelated individuals, such as occurred in the other two regions.

Recovery Criterion 2 – Adequate Population Connectivity. A rate of natural dispersal, between primary core populations of the size specified above, of 0.5 genetically effective migrants per generation, is sufficient to alleviate threats to viability arising from loss of genetic variation. This rate was also feasible given rates observed in other regions, and
taking into account the lower levels of habitat connectivity evident between potential primary core populations of Mexican wolves.

**Recovery Criterion 3 – Stable Population Trend.** A stable or increasing population trend over 2 generations supports the conclusion that threats have been adequately alleviated.

**Recovery Criterion 4 – Post-delisting Monitoring.** Continued population monitoring is necessary to ensure that the subspecies does not again fall to threatened or endangered status.

**Recovery Criterion 5 - Regulatory mechanisms:** Adequate state management plans and other regulatory protection indicate that threats arising from inadequacy of regulatory mechanisms have been remedied.

**Rationale for Downlisting Criteria**

**Recovery Criterion 1 – Adequate Population Size.** The establishment of three primary core populations of 100 individuals each indicate reduction in threats to viability arising from loss of genetic variation and other factors.

**Recovery Criterion 2 – Stable Population Trend.** A stable or increasing population trend over 2 generations supports the conclusion that threats to population persistence have been reduced.

*Recovery Criterion 3 – Amelioration of human-caused mortality: Reduction in the estimated rate of human-caused losses to less than 17% supports the conclusion that threats to population persistence have been reduced.*

**Modeling Approach**
Several modeling tools are available to inform development of recovery criteria based on best available science. It is important to acknowledge the strengths and weaknesses of each type of model and to consider information from multiple models in an appropriate decision-support context. We employed state-of-the-art modeling tools in a multi-step analysis for evaluating alternative recovery criteria. Collectively, these modeling tools allow comparison of estimated population viability (probability of population recovery) and distribution among alternative recovery scenarios under a variety of potential conditions. The evaluation approach the modeling team developed consists of three main steps:

**Step 1 Population Simulation Model** - Because of the magnitude of genetic threats to the Mexican wolf, we selected a population simulation model (Vortex; Lacy et al. 2010) with the capability to explore how genetic threat factors vary with population size and metapopulation structure. This informs development of criteria for the size, number and connectivity of subpopulations.

**Step 2 Habitat-based Model** – The Vortex model lacks sophisticated treatment of spatial dynamics or habitat. Once Step 1 of criteria development is completed, a second stage of the process determined where on the landscape such criteria could be achieved given distribution of suitable habitat. Information sources for this second stage included results from a spatially-explicit population model (PATCH; Carroll et al. 2006).

**Step 3 Connectivity Model** - The Vortex analysis suggested that population connectivity was especially beneficial for persistence in Mexican wolves due the subspecies being derived from inbred and interrelated founders. We therefore examined what rate of natural dispersal between primary core populations was sufficient for population persistence and could be achieved given the distribution of suitable habitat. We did this by relating observed connectivity rates in other regions to relative habitat connectivity between primary core populations in those regions, and extrapolating to evaluate rates expected given habitat connectivity between potential primary core populations of Mexican wolves.
III. RECOVERY PROGRAM

(Note to Reviewer:)

A. Recovery Action Outline

Recovery actions are near-term recommendations to guide the activities needed to accomplish the recovery objectives and achieve the recovery criteria. This Recovery Plan presents actions that address overall recovery. These actions are organized following the five listing factors described earlier.

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; and

E. Other natural or manmade factors affecting its continued existence
B. Recovery Narrative
This table demonstrates how the recovery criteria and/or recovery actions ameliorate threats to the Mexican wolf.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Threat</th>
<th>Criteria</th>
<th>Recovery Action</th>
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IV. IMPLEMENTATION SCHEDULE
V. LITERATURE CITED

LITERATURE CITED (MASTER LIST – 4/21/2012)


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APPENDIX A. GLOSSARY AND LIST OF ABBREVIATIONS

3-Year Review  Mexican Wolf Recovery: Three Year Program Review and Assessment

5-Year Review  Mexican Wolf Blue Range Reintroduction Project 5-Year Review

AGFD  Arizona Game and Fish Department

AMOC  Adaptive Management Oversight Committee

AMOC and IFT  Adaptive Management Oversight Committee and Interagency Field Team, commonly used as a literature citation referencing these committees as authors of sections of the 5-Year Review, including the Technical Component (TC), Administrative Component (AC), or AMOC Recommendations

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, as designated by the Final Rule (50 CFR 17.84(k))

DPS  Distinct Population Segment

EIS  Environmental Impact Statement

ESA  Endangered Species Act of 1973, as amended

FAIR  Fort Apache Indian Reservation of the White Mountain Apache Tribe

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, 50 CFR 17.84(k)

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
<table>
<thead>
<tr>
<th>Code</th>
<th>Term</th>
<th>Description</th>
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<tbody>
<tr>
<td>SWDPS Recovery Team</td>
<td>Southwestern Gray Wolf Distinct Population Segment (with emphasis on the Mexican gray wolf, <em>Canis lupus baileyi</em>)</td>
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<td>USDA-WS</td>
<td>US Department of Agriculture-Animal Plant Health Inspection</td>
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<td>USFS</td>
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<td>WMAT</td>
<td>White Mountain Apache Tribe</td>
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