Draft Mexican Wolf Revised Recovery Plan

5_07_2012
TEAM USE ONLY
NOT FOR DISTRIBUTION

U.S. Fish and Wildlife Service
Southwest Region (Region 2)
Albuquerque, New Mexico
20xx

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.

ACKNOWLEDGEMENTS

The Service is grateful for expertise and dedication of the Mexican Wolf Recovery Team (team), which convened from 2011 to 20xx to develop this recovery plan. The team was comprised of four subgroups:

<u>Agency Liaison Group</u>

Bobbi Barrera, U.S. Department of Agriculture, Forest Service,
David Bergman, U.S Department of Agriculture, Animal and Plant Health Inspection Services, Wildlife Services
John Shivik, Kevin Bunnell, Utah Division of Wildlife Resources
Terry Johnson, Larry Riley, Arizona Game and Fish Department
Joseph Jojola, Bureau of Indian Affairs, U.S. Department of the Interior
R.J. Kirkpatrick (Resigned from team in 2011), New Mexico Department of Game and Fish
Elaine Leslie, National Park Service, U.S. Department of the Interior
Eric Odell, Colorado Parks and Wildlife
Martin Vargas Prieto, Direccion General de Vida Silvestre, Secretaria de Medio Ambiente y Recursos Naturales
Oscar Ramirez, Comision Nacional de Areas Naturales Protegidas
Julie Maitland, Bud Starnes, New Mexico Department of Agriculture

<u>Science and Planning Group</u>

Carlos Carroll, Klamath Center for Conservation Research
Rich Fredrickson, University of Montana
Jim Heffelfinger, Arizona Game and Fish Department
Kirsten Leong, National Park Service, U.S. Department of the Interior
Mike Phillips, Turner Endangered Species Fund
Jorge Servin, Universidad AutonomaMetropolitana-Xochimilco
Peter Siminski, The Living Desert (Team Leader)
Doug Smith, Yellowstone National Park, U.S. Department of the Interior
John Vucetich, Michigan Technological University

<u>Stakeholder Group</u>

Patrick Bray, Arizona Cattle Growers' Association
Caren Cowan, New Mexico Cattle Growers Association
Kim Crumbo, Grand Canyon Wildlands Council
Carey Dobson, Arizona Wool Producers Association
Howard Hutchinson, Coalition of Arizona and New Mexico Counties
Dave Parsons, The Rewilding Institute
Brad Powell, Arizona Wildlife Federation
Eva Lee Sargent, Defenders of Wildlife
Bob Atwood, New Mexico Council of Outfitters and Guides

<u>Tribal Liaison Group</u>

Cynthia Dale, White Mountain Apache Tribe

Sylvia Rains Dennis, Pueblo of Taos
Aaron Koehlinger, April Howard, San Carlos Apache Tribe
Adam Ringia, Pueblo of Laguna
Steve Whiteman, Southern Ute Indian Tribe

The following U.S. Fish and Wildlife Service (Service or USFWS) staff contributed guidance, oversight, and expertise to the development of this document: Benjamin N. Tuggle, Regional Director, Southwest Region; Wendy Brown, Recovery Coordinator, Southwest Region; Steve Chambers, Senior Scientist, Southwest Region; Sherry Barrett, Mexican Wolf Recovery Coordinator, Southwest Region; Maggie Dwire, Assistant Mexican Wolf Recovery Coordinator, Southwest Region; John Oakleaf, Senior Wolf Biologist, Southwest Region;Tom Buckley, Public Affairs Specialist, Southwest Region; Joe Early, Native American Liaison, Southwest Region; and Tracy Melbihess, Mexican Wolf Recovery Team Manager, Southwest Region.

(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:
U.S. Fish and Wildlife Service. 20xx. Draft Mexican Wolf Revised Recovery Plan. Region 2, Albuquerque, New Mexico, USA.

Copies of the document can be requested from:

U.S. Fish and Wildlife Service
New Mexico Ecological Services Field Office
2105 Osuna Drive NE
Albuquerque, New Mexico 87113
Telephone #: 505-346-2525 or 1-800-299-0196
Fax #: 505-346-2542

U.S. Fish and Wildlife Service
Southwest Regional Office
P.O. Box 1306
Albuquerque, New Mexico 87103-1306
Telephone #: 505-248-6920
Fax #: 505-248-6788

Copies are also available on-line at:
http://www.fws.gov/southwest/es/mexicanwolf

TABLE OF CONTENTS

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. <u>Status of the Species</u>

(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.

Mexico formally recognized the Mexican wolf as an endangered subspecies under the Norma Oficial Mexicana NOM-059-ECOL-1994, a Mexican Federal law protecting wildlife. The Mexican wolf subspecies continues to be protected under the Ley de Vida Silvestre (2000), Norma Oficial Mexicana NOM-059-ECOL-2001 (2002).

C. Description

(Note to Reviewer:)

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. <u>Taxonomy and Distribution</u>

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 Vilá 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-extermination 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. monstrabalis*, and *C.l. mogollenensis* (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-extermination 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 in to 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 publically 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.).

Mexico

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 (USFWS 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. 2007). Between 1998 and 2012, xx wolf dispersals (natural dispersals and post-release 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 suitable habitat usually establish a territory (Rothman and Mech 1979, Fritts and Mech 1981).

H. Ecology and Habitat Characteristics/Ecosystem

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

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 edulus*) and juniper (*Juniperus* spp.) to higher elevation pine (*Pinus* spp.) and mixed conifer forests. Factors making these habitats attractive to Mexican wolves likely included an abundance of 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 (mi^2) (200-400 square kilometers (km^2), and hypothesized that Mexican wolf territories were historically comparable in size to those of small packs of northern gray wolves, but possibly larger, due to habitat patchiness (that is, mountainous terrain that included areas of unsuitable lowland habitat) and lower prey densities associated with the arid environment. Between 1998 and 2010, home range size of 80 denning packs in the Blue Range population averaged 182 mi^2 +/- 24 mi^2 (464 km^2 +/- 298 km^2 (179 mi^2 +/- 115 mi^2) (John Oakleaf, pers. comm., 2012). The average home range size for 22 non-denning packs during the same time period was 330 mi^2 +/- 272 mi^2 (855km^2 +/- 704 km^2). 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 items available at that time (Messier 1994, Metz et al. 2012). Using kill rates from Stark et al. (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 km^2), 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/km^2 or 0.8/mi^2 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, ungulate 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 weight in Parsons (1995).

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/km^2). 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.

Area name	Total Size	Size Good habitat	Isolation (km)	Cattle	Deer biomass (DEPU)	Deer Biomass Best habitat	Prey biomass Best habitat	Wolves (per 1000 km^2)	Total wolves
Overall									
US									
1. Blue Range	>25,000		400	1-5	5.6			22	>250
2. Grand Canyon	>25,000		400	<1	4.1			17	>250
3. Carson/San Juans	>25,000		450	1-7	7.6			28	>250
4. Western Texas	24,000		250	1-3	2-4?			10-17?	200?
Mexico									
Best habitat									
1. Sierra San Luis/Ajos-Bavispe	25,900	15,700	300	5	1-2	2.41	2.89	13	80
2. Tutuaca/Sierra Tarahumara	21,200		300	4	1-2	2	2.4	11.4	80
3. Chihuahua/Durango	29,975	8,300	350	7	1-2	3.6	4.32	17.8	60
4. Sierra de Valparaiso/Sierra de Urica/Mezquital	12,667		350	6	1-2	0.68	0.82	6.2	24
5. Maderas del Carmen/Serranias de Burro	19,564		250	6	1-2	0.6	0.72	5.9	85-100
6. Sierra Plegada	17,968		450	7	1-2	0.23	0.28	4.4	60-140

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 km^2) and adjacent of Kaibab and Coconino NF lands (13,300 km^2). 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 km^2), Santa Fe National Forest (6,400 km^2), Vermejo Park Ranch (2,300 km^2), 268 km^2 of additional private lands protected under conservation easements, and the Taos Pueblo (391 km^2) of which 230 km^2 are managed as wilderness by the tribe. The Valle Vidal Unit of the Carson National Forest (407 km^2) 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 km^2), Rio Grande National Forests (7,440 km^2), and Grand Mesa, Uncompahgre, and Gunnison National Forests (12,600 km^2). The San Juan Mountains contain 4,000 km^2 of Wilderness Areas and 4,000 km^2 roadless areas including significant lower-elevation ecosystems. Relatively low levels of livestock grazing occur on the San Juan NF (Bennett 1994).

Similarly to the Grand Canyon, the northern New Mexico/southern Colorado core area would aid the reestablishment of well-distributed wolf populations northward to the public lands in western Colorado. However, these sites appear to have somewhat higher vulnerability to habitat reduction or isolation by landscape change than does the Grand Canyon region (Carroll et al. 2005). This is due to a higher proportion of private lands in lower elevation valleys, as well as the generally higher predicted rate of landscape change in Colorado and New Mexico (Carroll et al. 2005).

4. Western Texas: Approximately 24,000 km^2 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 km^2 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 2. Based on ungulate biomass and their areal extent each of the three core areas identified are expected to support > 250 wolves.

Core Area	Area (km^2) with 60%+ Predicted Wolf Occupancy	UBI based on all Deer & Elk	Predicted wolf density (/1000km^2 based on Deer & Elk)	Predicted No. of Wolves (based on Deer & Elk)	UBI based on Elk only	Predicted wolf density (/1000km^2 based on Elk only)	Predicted No. of Wolves (based on Elk only)
CO/NM Border	11,500	7.6	28	322	6.5	25	288
Grand Canyon/UT	23,000	4.1	17	391	2.6	12	276
Mogollon Rim/BRWRA	20,500	5.6	22	442	4.5	18	369

Effects of Future Landscape Change on Habitat in the US

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.

Connectivity between US core areas

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 km^2) was predicted to be suitable for wolves under these assumptions, whereas little habitat remained in other areas such as Nuevo Leon and Tamaulipas (Servín 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 (<100km^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 km^2, which would correspond to densities of 10-17 wolves/1000 km^2 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 km^2, 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 Tamualipas (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/km^2 for pasture and 2.0 km/km^2 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 Cohuila (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 km^2 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 km^2 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)

<u>1. Sierra San Luis and Ajos-Bavispe (Sonora/Chihuahua) Complex:</u> This area, of 10-15,000 km^2 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 km^2. Livestock density is approximately 5 cattle per km^2. In October 2011, five wolves were released in this area. Araiza et al. (2006) estimated that the area could support 80 wolves.

<u>2. Tutuaca and Sierra Tarahumara (Chihuahua) Complex:</u> This area, of 10,000 km^2 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 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 4 cattle per km^2. 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. Servin, 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 km^2 in extent. Core areas identified by Araiza et al. (2006) in Mexico were 6,000-17,000 km^2 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 km^2 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 km^2 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)/km^2 vs. 2-4 deer/km^2 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.

<u>Mexican Wolf is a Close Living Relative to the Gray Wolf Subspecies That Occupied the Areas Historically</u>

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.

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

<u>Mexican Wolf in Greatest Need of Conservation Assistance</u>

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.

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

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 integradation (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.

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

*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).

<u>State Policies</u>

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 Direccion General de la Fauna Silvestre. In both nations, Federal agencies lead the recovery efforts: Mexico's Direccion 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.

<u>Local and Regional Culture</u>

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…)

Factor A: Habitat Attribute	**Stressor**	**Geographic Scope**	**Severity / Intensity**	**Occurrence (Past/present/future; single episode vs. continuous; regular vs. sporadic; likelihood)**	**Overall Magnitude**	**Response**
Prey Availability / Biomass						
	Forage production					
	Competition between livestock and other prey for forage					
	Spread of non-native vegetation (inedible? lower nutrition?)					
	Change in vegetation due to livestock grazing (inedible? lower nutrition?)					
	Wolf predation					Ungulate mortality
	Ungulate Disease (See Factor C.)					Ungulate mortality; ___ in wolves
Habitat Quantity to Support Core Populations						

	Increasing urbanization						Decreased ability for natural wolf range expansion; decreasing habitat availability over time in areas of low human inhabitance; increased likelihood of wolf-human interactions
	Increasing road density / traffic						Mortality from vehicular collision; behavior modification? (denning, dispersal)
	Quantity of public land						Private lands have a greater potential for human-wolf interactions
	Wildfire						Mortality; prey availability?

	Climate Change					
	Regional Drought Cycles					Mortality? Prey availability?
Habitat Connectivity to Support Migration Between Subpopulations						
	Increasing urbanization in US and Mexico					
	Increasing road density / traffic in US and Mexico					Mortality from vehicular collision during dispersal events; no genetic exchange between subpopulations
	Borderlands activities and infrastructure					
Habitat Quality						
	Increasing urbanization in US and Mexico					Behavior disturbance (
	Regional Drought					

	Cycles					
	Climate Change					
	Wildfire					
Factor B. Overutilization						
Incidental take by FWS and partner agencies	Vaccinations and medical treatment; capture and control actions					Mortality
Factor C. Disease						
Rabies						
	Transmission by domestic canids					Mortality
	Transmission by wild canids or other animals					Mortality
	Lack of labeled vaccines for wolves					
Parvovirus						
	Transmission by domestic canids					Mortality
	Transmission by wild canids or other animals					
Distemper						
	Transmission by domestic canids					
	Transmission by wild canids					

Corona virus						
Chronic wasting disease						Mortality to ungulates;
Predation (on wolf by other predators)	Competition between predators					Mortality
Factor D. Regulatory Mechanisms						
Legislative efforts to delist wolves in UT, AZ, NM	public opinion					
Illegal / accidental take of Mexican wolves						
	McKittrick policy / difficulty successfully prosecuting offenders					
	Nighttime spotlight hunting					
	Misidentification					
	Lack of law enforcement capacity					
Progress / status of BRWRA						

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						
Mechanisms that reduce forage (repetitive with factor A?)	Competing management regimes stemming from single species management focus (e.g., MSO vs MW?)					
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						
Factor E. Other						
Tribal participation in recovery						
	Lack of funding, economic impacts					
	Competing land uses					
	Cultural values					
Stakeholder participation in recovery						
	Inadequate public education					
	Social and economic impacts					
	USFWS intolerance of local communities, culture					
Lack of funding to support recovery implementation						
	Political support					
Interagency coordination to support recovery						

Foothold traps						
Human tolerance						
	Release sites too close to human inhabitance					
	Fear of wolves, negative perceptions of wolves					
	Dislike of federal government					
	Economic impacts of reintroduction					
	Wolf habituation to humans					
Progress of BRWRA						
	Lack of response to 3 year and 5 reviews					
	Depredation and boundary related removals					
	Human-caused mortality (all sources; poisoning, road kill, other)					
	Lack of incentives, funding, resources to support implementation, esp. in local communities to reduce interactions,					

	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					
Genetic health						
	Lack of gene flow					
	Hybridization with dogs and coyotes					
	Genetic swamping by northern wolves					
	Low levels of genetic variation, lack of robustness					
	Limited capacity of captive breeding program					
Use of livestock protection collars						

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. <u>Biological Constraints and Needs</u>

(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 (*Odocoileu svirginianuscouesi*) 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* *availability of prey.*"

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. <u>Binational Coordination for Mexican Wolf Recovery</u>

(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 Direccion General de Vida de la Fauna Silvestre. In both countries, Federal agencies lead the recovery efforts: Mexico's Direccion General de Vida Silvestre (DGVS) and the U.S. Fish and Wildlife Service. Both countries have comparable advisory committees for recovery: Mexico's Subcomite Technico 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

(Note to Reviewer:)

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;

6. Conserve genetic diversity and adaptive potential.

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 give 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

C. Threats Tracking Table

This table demonstrates how the recovery criteria and/or recovery actions ameliorate threats to the Mexican wolf.

Factor	**Threat**	**Criteria**	**Recovery Action**	

IV. IMPLEMENTATION SCHEDULE

V. LITERATURE CITED

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

Abbitt, R. J. F., J. M. Scott, and D. S. Wilcove. 2000. The geography of vulnerability: incorporating species geography and human developments patterns into conservation planning. Biological Conservation 96:169? 175.

Adams, H.D., M. Guardiola?Claramonte, G.A. Barron-Gafford, J.C. Villegas, D.D. Breshears, C.B. Zou, P.A. Troch, and T.E. Huxman. 2009. Temperature sensitivity of drought?induced tree mortality portends increased regional die?off under global?change?type drought. Proceedings of the National Academy of Sciences 106:7063?7066.

Adams, J. R, L. M. Vucetich, P. W. Hedrick, R. O. Peterson, and J. A. Vucetich. 2011. Genomic sweep and potential genetic rescue during limiting environmental conditions in an isolated wolf population. Proceedings of the Royal Society B (online early).

Adams, L. G., R. O. Stephenson, B. W. Dale et al. 2008. Population dynamics and harvest characteristics of wolves in the Central Brooks Range, Alaska. Wildlife Monographs 170: 1-25

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

Allendorf , F. W., and N. Ryman. 2002. The role of genetics in population viability analysis. Pages 50-85 in S. R. Beissinger, D. R. McCullough, eds. Population Viability Analysis. University of Chicago Press, Chicago, Illinois.

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

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

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

Anderson, E., S. C. Forrest, T. W. Clark, and L. Richardson. 1986. Paleobiology, biogeography, and systematics of the black?footed ferret, Mustela nigripes (Audubon and Bachman), 1851. Great Basin Naturalist Memoirs.

Araiza Ortiz, M. A. 2002. Determinación de sitios potenciales para la reintroducción del lobo mexicano (Canis lupus baileyi) en Sonora, Chihuahua y Coahuila, México.

Araiza, M., Carrillo, L., List, R., Martínez, P., Martínez, E., Moctezuma, O., Sánchez, N., Servín, J. 2006. Taller para la Reintroducción del Lobo Mexicano (Canis lupus baileyi) en México. Reporte Final. IUCN/SSC Grupo Especialista en Conservación y Cría, Oficina Regional México.

Araiza, M., L. Carrillo, R. List, C. A. López González, E. Martínez Meyer, P. G. Martínez Gutiérrez, O. Moctezuma, N. E. Sánchez-Morales, and J. Servín. In press. Towards a consensus of areas with potential for wolf reintroduction in Mexico. Conservation Biology.

Araiza, M., L. Carrillo, R. List, P. Martínez, E. Martínez, O. Moctezuma, N. Sánchez, and J. Servín, editors. 2006. Mexican wolf reintroduction workshop: evaluation of potential release sites. Final Report. Mach 8-10, 2006. El Manzano, Nuevo Leon, MX.

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

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

Arizona Game and Fish Department [AGFD], and U.S. Fish and Wildlife Service. 2002. Interagency Field Team Report (reporting period January 1 – December 31, 2002).

Arizona Game and Fish Department [AGFD], New Mexico Department of Game and Fish, U.S. Department of Agriculture - Animal and Plant Health Inspection Service - Wildlife Services, U.S. Fish and Wildlife Service, and White Mountain Apache Tribe. 2004. Mexican wolf Blue Range reintroduction project: interagency field team report (reporting period January 1-December 31, 2004).

Arizona Game and Fish Department [AGFD], New Mexico Department of Game and Fish, U.S. Department of Agriculture - Animal and Plant Health Inspection Service - Wildlife Services, U.S. Fish and Wildlife Service, and White Mountain Apache Tribe. 2005. Mexican wolf Blue Range reintroduction project: interagency field team report (reporting period January 1-December 31, 2005).

Arizona Game and Fish Department [AGFD], New Mexico Department of Game and Fish, U.S. Department of Agriculture - Animal and Plant Health Inspection Service - Wildlife Services, U.S. Fish and Wildlife Service, and White Mountain Apache Tribe. 2006. Mexican wolf Blue Range reintroduction project: interagency field team report (reporting period January 1-December 31, 2006).

Arizona Game and Fish Department [AGFD], New Mexico Department of Game and Fish, U.S. Department of Agriculture - Animal and Plant Health Inspection Service - Wildlife

Services, U.S. Fish and Wildlife Service, and White Mountain Apache Tribe. 2007. Mexican wolf Blue Range reintroduction project: interagency field team report (reporting period January 1-December 31, 2007).

Arizona Game and Fish Department [AGFD], New Mexico Department of Game and Fish, U.S. Department of Agriculture - Animal and Plant Health Inspection Service - Wildlife Services, U.S. Fish and Wildlife Service, and White Mountain Apache Tribe. 2008. Mexican wolf Blue Range reintroduction project: interagency field team report (reporting period January 1-December 31, 2008).

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

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

Aspi, J., E. Roininen, M. Ruokonen, I. Kojola, and C. Vila. 2006. Genetic diversity, population structure, effective population size and demographic history of the Finnish wolf population. Molecular Ecology 15: 1561-1576.

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

Association of Zoos and Aquariums [AZA]. 2008a. Letter to Benjamin Tuggle, USFWS Regional Director, Region 2, Duane Shroufe, AGFD Director, Bruce Thompson, NMDFG Director. Re: A request for a moratorium on lethal control and permanent removal (rescind or suspend SOP13) of Mexican wolves in the Blue Range Wolf Recovery Area until an expert taskforce on genetic issues can be convened to provide guidance to these actions. January 2, 2008.

Bachelet, D., J. M. Lenihan, C. Daly, R. P. Neilson, D. S. Ojima, and W. J. Parton. 2001. MC1: a dynamic vegetation model for estimating the distribution of vegetation and associated carbon, nutrients, and water -- technical documentation. Version 1.0. General Technical Report PNW-GTR-508. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Backhoff Pohls, M. A., G. G. Ortega, and J. C. Vázquez Paulín. 2000. Desarollo del sistema de informacion geoestadistica para el transporte y aplicaciones multitematicas derivadas. Proceedings of ESRI Users Conference. Available at http://gis.esri.com/library/userconf/latinproc00/mexico/sig_transporte.pdf Accessed April 2003.

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

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

Ballard, W.B., B.R Farnell, and R.O. Stephenson. 1983. Long distance movements by gray wolves. Canadian Field Naturalist. 97:333

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

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

Ballard, W. B., D. Lutz, T. W. Keegan, L. H. Carpenter, and J. C. deVos, Jr. 2001. Deer-Predator Relationships: A Review of Recent North American Studies with Emphasis on Mule and Black-Tailed Deer. *Wildlife Society Bulletin* 29:99-115.

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

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

Bangs, E. E., and S. H. Fritts. 1996. Reintroducing the gray wolf to central Idaho and Yellowstone National Park. Wildlife Society Bulletin 24:402-413.

Bangs, E. E., S. H. Fritts, J. A. Fontaine, D. W. Smith, K. M. Murphy, C. M. Mack, and C. C. Niemeyer. 1998. Status of gray wolf restoration in Montana, Idaho, and Wyoming. Wildlife Society Bulletin 26:785-798.

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

Baril, L.M., A. J Hansen, R. Renkin, and R. Lawrence. 2011. Songbird response to increased willow (*Salix* spp.) growth in Yellowstone's northern range. Ecological Applications 21:2283-2296.

Bednarz, J. C. 1989. An evaluation of the ecological potential of White Sands Missile Range to support a reintroduced population of Mexican wolves. Endangered Species Report 19. U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 96 pp.

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

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

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

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

Bogan, M. A., and P. Mehlhop. 1983. Systematic relationships of gray wolves (Canis lupus) in southwestern North America. Occasional papers of the Museum of Southwestern Biology No. 1. 21 pp.

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

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

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

Boyce, M. S., and L. L. MacDonald. 1999. Relating populations to habitats using resource selection functions. Trends in Ecology & Evolution 14:268-272.

Boyce, M.S., Sinclair, A.R.E. & White, G.C. (1999) Seasonal compensation of predation and harvesting, Oikos 87, 419-426.

Boyd, D. K., P. C. Paquet, S. Donelson, R. R. Ream, D. H. Pletscher, and C. C. White. 1995. Transboundary movements of a recolonizing wolf popuation in the Rocky Mountains. Pages 135 – 140 in L. N. Carbyn, S. H. Fritts, and D. R. Seip, eds. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, Occassional Publication No. 35. 642 pp.

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

Bradshaw, A. D. 2002. Introduction and philosophy. Pages 3?10 in M. R. Prrow and A. J. Davy, eds. Handbook of ecological restoration. Cambridge University Press, Cambridge.

Brainerd, S.M., H. Andren, E.E. Bangs, E.H. Bradley, J.A. Fontaine, W. Hall, Y. Iliopoulos, M.D. Jimenez, E.A. Jozwiack, O. Liberg, C.M. Mack, T.J. Meier, C.A. Niemeyer, H.C. Pedersen, H. Sand, R.N. Schultz, D.W. Smith, P. Wabakken, and A.P. Wydeven. 2008. The effects of breeder loss on wolves. Journal of Wildlife Management 72:89-98.

Breitenmoser, U., C. Breitenmoser-Würsten, L. N. Carbyn, and S. M. Funk. 2001. Assessment of carnivore reintroductions. Pages 241-281 in J. L. Gittleman, S. M. Funk, D. W. MacDonald, and R. K. Wayne, editors., Carnivore Conservation. Cambridge University Press, Cambridge, United Kingdom.

Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Meyer. 2005. Regional vegetation dieoff in response to global change type drought. Proceedings of the National Academy of Sciences 102:15144?15148.

Brewster, W. G., and S. H. Fritts. 1995. Taxonomy and genetics of the gray wolf in western North America: a review. Pages 353-374 in L. N. Carbyn, S. H. Fritts, and D. R. Seip, eds. Ecology and conservation of wolves in a changing world. Occasional Publication No 35, Canadian Circumpolar Institute, Edmonton, Alberta. 642 pp.

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

Brown, D. E., editor. 1983. The wolf in the southwest: the making of an endangered species. University of Arizona Press, Tucson, Arizona. 195 pp.

Brown, D. E., and C. A. Lopez Gonzalez. 2001. Borderland jaguars: tigres de la frontera. University of Utah Press, Salt Lake City.

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

Brown, L. 2011. World on the edge: how to prevent environmental and economic collapse. W.W. Norton & Company, New York. 240 pp.

Brown, T.L., Siemer, W.F. & Decker, D.J. (2001) Human Dimensions of Wildlife Management in North America , The Wildlife Society, Bethesda, Md.

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

Cantú, C., J.M. Scott y R.G. Wright. 2001. The Gap Analysis Program on the assessment of nature reserves of Mexico. Gap Analysis Bulletin 10. Accessed at <www.gap.uidaho.edu/Bulletins/10/bulletin10_TOC.htm>.

Carmichael, L. E., J. Krizan, J. A. Nagy, E. Fuglei, M. Dumond, D. Johnson, A. Veitch, D. Berteaux, and C. Strobeck. 2007. Historical and ecological determinants of genetic structure in arctic canids. Molecular Ecology 16:3466–3483.

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

Carroll, C., J. A. Vucetich, M. P. Nelson, D. J. Rohlf, and M. K. Phillips. 2010. Geography and recovery under the U. S. Endangered Species Act. Conservation Biology 24:395-403.

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

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

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

Carroll, C., R. F. Noss, P. C. Paquet, and N. H. Schumaker. 2003b. Use of population viability analysis and reserve selection algorithms in regional conservation plans. Ecological Applications 13:1773-1789.

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

Carroll, C., R. F. Noss, N. H. Schumaker, and P. C. Paquet. 2001b. Is the restoration of wolf, wolverine, and grizzly bear to Oregon and California biologically feasible?. Pages 25-46 in D. Maehr, R. Noss, and J. Larkin, editors. Large mammal restoration: ecological and social implications. Island Press, Washington, D.C.

Carroll, C. 2010. Role of climatic niche models in focal-species-based conservation planning: assessing potential effects of climate change on Northern Spotted Owl in the Pacific Northwest, USA. Biological Conservation 143:1432-1437.

Carroll, C., B. McRae, and A. Brookes. 2011. Use of linkage mapping and centrality analysis across habitat gradients to conserve connectivity of gray wolf populations in western North America. Conservation Biology Online Early.

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

CDOW (Colorado Division of Wildlife Resources). 1997. Big game hunting statistics. A Colorado outdoors special edition. CDOW, Denver.

Chambers, S. M., S. R. Fain, B. Fazio, and M. Amaral. Submitted. An account of the taxonomy of North American wolves from morphological and genetic analyses.

Channel, R., and M. V. and Lomolino. 2000b. Trajectories toward extinction: spatial dynamics of the contraction of endangered species. Journal of Biogeography 27:169?179.

Channel, R., and M. V. Lomolino. 2000a. Dynamic biogeography and conservation of endangered species. Nature 403:84?86.

Chen, I., J., K. Hill, R. Ohlemuller, D. B. Roy, and C. D. Thomas. 2011. Rapid range shifts of species associated with high levels of climate warming. Science 333:1024?1026.

Cihlar, J., L. St.-Laurent, and J. A. Dyer. 1991. Relation between the normalized difference vegetation index and ecological variables. Remote Sensing of the Environment 35:279-298.

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

Cooley, H. S., Wielgus R. B., Koehler G. M., Robinson, H. S. & Maletzke, B. T. (2009) Does hunting regulate cougar populations? A test of the compensatory mortality hypothesis. Ecology 90, 2913-2921.

Coronel-Arellano, H., C. A. López González, and C. N. Moreno Arzate. 2009. ¿Pueden las variables de paisaje predecir la abundancia de venado cola blanca? El caso del noroeste de México. Tropical Conservation Science 2: 229-236.

Crandall, K.A., O. R. P. Bininda-Emonds , G. M. Mace, and R. K. Wayne. 2000. Considering evolutionary processes in conservation biology. Trends in Ecology and Evolution 15:290-295.

Creel, S., and J. J. Rotella. 2010. Meta-Analysis of Relationships between Human Offtake, Total Mortality and Population Dynamics of Gray Wolves (Canis lupus). PLoS ONE 5:e12918.

Creel, S., and N. M. Creel. 1998. Six ecological factors that may limit African wild dogs, Lycaon pictus. Animal Conservation 1:1-9.

Crist, E. P., and R. C. Cicone. 1984. Application of the tasseled cap concept to simulated thematic mapper data. Photogrammetric Engineering and Remote Sensing 50:343-352.

Daly, C., D. Bachelet, J. M. Lenihan, R. P. Neilson, W. Parton, and D. Ojima. 2000. Dynamic simulation of tree-grass interactions for global change studies. Ecological Applications 10:449-469.

Daly, C., R. P. Neilson, and D. L. Phillips. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. Journal of Applied Meteorology 33: 140-158.

DenBoer, P. J. 1968. Spreading of risk and stabilization of animal numbers. Acta Biotheoretica 18:165- 194.

DiMento, J. F. C., and P. Doughman. 2007. Climate change: what it means for us, our children, and our grandchildren. The MIT Press, Cambridge, Massachusetts. 217 pp.

Draper, N.R. & Smith H (1998) Applied Regression Analysis, Wiley-Interscience, New York.

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

Elith, J., and J. R. Leathwick. 2009. Species distribution models: ecological explanation and prediction across space and time. Annual Review of Ecology, Evolution and Systematics 40:677–697.

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

Ewins, P., M. de Almeida, P. Miller and O. Byers, eds. 2000. Population and Habitat Viability Assessment Workshop for the Wolves of Algonquin Park: Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN.

Falk, D.A. 1990. Discovering the Future, Creating the Past: Some Reflections on Restoration. Restoration & Management Notes 8: 71.

Flather, C. H., G. D. Hayward, S. R. Beissinger, and P. A. Stephens. 2011. Minimum viable populations: is there a 'magic number' for conservation practitioners? Trends in Ecology and Evolution 26:307-316.

Foley, P. (1994) Predicting extinction times from environmental stochasticity and carrying-capacity. Conservation Biology 8, 124-137

Forbes, S., H., and D. K. Boyd. 1996. Genetic variation of naturally colonizing wolves in the central Rocky Mountains. Conservation Biology 10:1082?1090.

Frankel, O. H., and M E. Soulé . 1981. Conservation and evolution. Cambridge University Press, Cambridge, UK.

Frankham, R. 1995. Effective population size/adult population size ratios in wildlife: a review. Genetical Research 66:95-107.

Frankham, R. 2008. Genetic adaptation to captivity in species conservation programs. Molecular Ecology 17:325-333.

Frankham, R. 2010. Challenges and opportunities of genetic approaches to biological conservation, Biological Conservation 143:1919-1927.

Frankham, R., J. D. Ballou, D. A. Briscoe. 2002. Introduction to Conservation Genetics. Cambridge University Press, Cambridge, UK.

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

Franklin, I.R., and R. Frankham. 1998. How large must populations be to retain evolutionary potential? Animal Conservation 1:69-70.

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

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

Fritts, S. H. 1983. A record dispersal by a wolf from Minnesota. Journal of Mammalogy 64:166-167.

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

Fritts, S. H., E. E. Bangs, J. A. Fontaine, M. R. Johnson, M. K. Phillips, E. D. Koch, and J. R. Gunson. 1997. Planning and implementing a reintroduction of wolves to Yellowstone National Park and central Idaho. Restoration Ecology 5:7?27.

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

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

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

Fryxell, J. M., Packer, C., McCann, K., Solberg, E.J. & Sæther, B.-E. (2010) Resource management cycles and the sustainability of harvested wildlife populations, Science 328, 903-906.

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

Fuller, T. K. 2010. Synthesis of expert comments on the Draft Wolf Conservation and Management Plan for Washington. Washington State Department of Fish and Wildlife, Olympia, WA.

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

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

Fuller, W. A. (1987) Measurement Error Models, New York, Wiley.

Garcia-Moreno, J., M. D. Matocq, M. S. Roy, E. Geffen, and R. K. Wayne. 1996. Relationships and genetic purity of the endangered Mexican wolf based on analysis of microsatellite loci. Conservation Biology 10:376-389.

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

Geffen, E., M. J. Anderson, and R. K. Wayne. Climate and habitat barriers to dispersal in the highly mobile gray wolf. Molecular Ecology

Gese, E.M., and L.D. Mech. 1991. Dispersal of wolves (Canis lupus) in northeastern Minnesota, 1969-1989. Canadian Journal of Zoology 69:2946-2955.

Gilpin, M. E. 1987. Spatial structure and population viability. Pages 125–139 in M. E. Soulé, editor. Viable populations for conservation. Cambridge University Press, Cambridge, UK.

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

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

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

Gish, D. M. 1977. An historical look at the Mexican gray wolf (Canis lupus baileyi) I early Arizona Territory and since statehood. Unpublished typescript. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Gittleman, J. L., S. M. Funk, D. W. MacDonald, and R. K. Wayne, editors. 2001. Carnivore conservation. Cambridge University Press, Cambridge, United Kingdom.

Goldman, E. A. 1937. The wolves in North America. Journal of Mammalogy 18:37-45.

Goldman, E. A. 1944. The wolves of North America. Part 2. Classification of wolves. Pages 389 – 636 in S. P. Young and E. A. Goldman, eds. The wolves of North America. Dover, New York and American Wildlife Institute, Washington, D.C.

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

Green-Hammond, K.A. 1994. Assessment of impacts to populations and human harvests of deer and elk caused by the reintroduction of Mexican wolves. Contractor report to the U.S. Fish and Wildlife Service, Albuquerque, NM. 3O pp.Grinnell, J. 1917. The niche-relationships of the California Thrasher. Auk 34: 427-433.

Groebner, D. J., Girmendonk, A. L., and Johnson, T. B. 1995 .A proposed cooperative reintroduction plan for the Mexican wolf in Arizona. Technical Report 56. Nongame and Endangered Wildlife Program. Arizona Game and Fish Department, Phoenix, Arizona.

Gude, J.A., Mitchell, M.S., Russell, R. E., Sime, C. A., Bangs, E. E., Mech, L. D. & Ream R. R. (2011) Wolf population dynamics in the U.S. northern rocky mountains are affected by recruitment and human-caused mortality. Journal of Wildlife Management, DOI: 10.1002/jwmg.201

Haight, R. G., D. J. Mladenoff, and A. P. Wydeven. 1998. Modeling disjunct gray wolf populations in semi-wild landscapes. Conservation Biology 12:879-888.

Hall, E. R., and K. R. Kelson. 1959. The mammals of North America. The Ronald Press Company, New York. 1083 pp.

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

Hansen, J. 2009. Storms of my grandchildren: the truth about the coming climate catastrophe and our last chance to save humanity. Bloomsbury Publishing, New York. 303 pp.

Hansen, J., et al. 2008. Target atmospheric CO2: where should humanity aim? Open Atmospheric Science Journal 2:217?231.

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

Harrison, D.J. and T.G. Chapin. 1998. Extent and connectivity of habitat for wolves in eastern North America. Wildlife Society Bulletin 26(4):767-775.

Hebblewhite, M., C.A. White, C.G. Nietvelt, J.A. McKenzie, T.E. Hurd, J.M. Fryxell, S.E. Bayley, and P.C. Paquet. 2005. Human activity mediates a trophic cascade caused by wolves. Ecology 86 (8):2135-2144.

Hebblewhite, M. and D. Smith. 2010. Wolf community ecology: Ecosystem effects of recovering wolves in Banff and Yellowstone National Parks. In: The world of wolves: New perspectives on Ecology, behavior and management. Editors: M. Musiani, L. Boitani, and P.C. Paquet.

Hedrick PW (2005) ''Genetic restoration'': a more comprehensive perspective than ''genetic rescue''. Trends Ecol Evol 20:109.

Hedrick, P. W., and R. J. Fredrickson. 2008. Captive breeding and the reintroduction of Mexican and red wolves. Molecular Ecology 17: 344–350.

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

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

Hedrick, P. W., R. J. Fredrickson. 2010. Genetic rescue: guidelines an example from Mexican wolves and Florida panthers. Conservation Genetics 11: 615–626.

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

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

Helí Coronel Arellano1, Carlos A. López González1, y Claudia N. Moreno Arzate2 2009. ¿Pueden las variables de paisaje predecir la abundancia de venado cola blanca? El caso del noroeste de México. Tropical Conservation Science Vol.2(2):229-236.

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

Houts, M. E. 2000. Modeling gray wolf habitat in the Northern Rocky Mountains using GIS and logistic regression. M.S. thesis. University of Kansas, Lawrence.

Huete, A. R., H. Q. Liu, K. Batchily, and W. van Leeuwen. 1997. A comparison of vegetation indices over a global set of TM images for EOS-MODIS. Remote Sensing of the Environment 59:440-451.

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

Instituto Nacional de Estadistica Geografia e Informatica (INEGI). 2000a. Mapa de vegetación y uso de suelo de México. INEGI. México.

Instituto Nacional de Estadistica Geografia e Informatica (INEGI). 2000b. Principales resultados por localidad, XII censo general de poblacion y vivienda. INEGI, Mexico City.

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

Jenks, S. M., and R. K. Wayne. 1992. Problems and policy for species threatened by hybridization. The red wolf as a case study. Pp. 237-251 in D. R. McCullough and R. H. Barrett. Eds. Wildlife 2001: Populations. Elsevier Applied Science, London.

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

Kaartinen, S., I. Kojola, and A. Colpaert. 2005. Finnish wolves avoid roads and settlements. Annales Zoologici Fenici 42:523-532.

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

Karieva, P., and U. Wennergren. 1995. Connecting landscape patterns to ecosystem and population processes. Nature 373:299-302.

Karieva, P., D. Skelly, and M. Ruckelshaus. 1996. Reevaluating the use of models to predict the consequences of habitat loss and fragmentation. Pages 156-166 in S. T. A. Pickett, R.S. Ostfeld, M. Schachak, and G. E. Likens, editors. The ecological basis of conservation: heterogeneity, ecosystems, and biodiversity. Chapman and Hall, New York.

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

Kokko, H. (2001) Optimal and suboptimal use of compensatory responses to harvesting: timing of hunting as an example. Wildlife Biology 7, 141–150.

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

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

Lacy, R. C. 1993. VORTEX: a computer simulation model for population viability analysis. Wildlife Research 20:45-65.

Lacy, R. C., M. Borbat, and J. P. Pollak. 2010. VORTEX: A Stochastic Simulation of the Extinction Process. Version 10.0. Brookfield, IL: Chicago Zoological Society.

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

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

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

Lande, R., Saether B.-E. & Engen, S. (1997) Threshold harvesting for sustainability of fluctuating resources, Ecology 78, 1341-1350.

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

Lara-Díaz , N. E.. 2010. La comunidad de mamíferos previa a la liberación de Canis lupus baileyi en Sonora, México. Master's thesis, Universidad Autónoma De Querétaro.

Lara-Díaz, N. E., H. Coronel-Arellano, A. González-Bernal,C. Gutiérrez-González, and C. A. López-González. 2011. Abundancia y densidad de venado cola blanca (Odocoileus virginianus couesi) en Sierra de San Luis, Sonora, México. Therya 2: 125-137.

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

Leopold, A. S. 1959. Wildlife of Mexico: the game birds and mammals. University of California Press, Berkeley.

Liberg, O., H. Andren, H. C. Pedersen, H. Sand, D. Sejberg, P. Wabakken, M. Åkesson, and S. Bensch. 2005. Severe inbreeding depression in a wild wolf (Canis lupus) population. Biology Letters, 1, 17-20.

Liberg, O., G. Chapron, P. Wabakken, H. C. Pedersen, N. T. Hobbs, and Håkan Sand. 2012. Shoot, shovel and shut up: cryptic poaching slows restoration of a large carnivore in Europe. Proc. Royal Society B 279:910-915.

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

List, R. 2007. The impacts of the border fence on wild mammals. Pp. 77 – 86. En: A barrier to our shared environment: the border wall between Mexico and the United States. A. Córdova y C. A. de la Parra (Eds.). SEMARNAT, Instituto Nacional de Ecología, El Colegio de la Frontera Norte. México, D. F. 206 pp.

Lomolina, M. V., and R. Channell. 1998. Range collapse, reintroductions, and biogeographic guidelines for conservation. Conservation Biology 12:481?484.

Lomolino, M. V. 2006. Space, time, and conservation biogeography. Pages 61?69 in J. M. Scott, D. D. Gobles, and F, W. Davis, eds. Endangered Species Act at Thirty: conserving biodiversity in human?domintated landscapes. Island Press, Washington, D.C. 360 pp.

Lomolino, M. V., and R. Channell. 1995. Splendid isolation: patterns of range collapse in endangered mammals. Journal of Mammalogy. 76:335?347.

Lynch, M., and R. Lande. 1998. The critical effective size for a genetically secure population. Animal Conservation 1:70-72.

MacArthur, R. H. 1972. Coexistence of species. Pp. 253-259 in J. Benke, ed., Challenging Biological Problems. Oxford Univ. Press.

MacNulty, D.R., L.D. Mech, and D.W. Smith. 2007. A proposed ethogram of large-carnivore predatory behavior, exemplified by the wolf. Journal of Mammalogy 88:596-605.

MacNulty, D.R., D.W. Smith, L.D. Mech, and L.E. Eberly. 2009a. Body size and predatory performance in wolves: is bigger better? Journal of Animal Ecology

MacNulty, D.R. D.W. Smith, J.A. Vucetich, L.D. Mech, D.R. Stahler, and C Packer. 2009b. Predatory senescence in ageing wolves. Ecology Letters 12: 1-10.

MacNulty, D.R., D.W. Smith, L.D. Mech, J.A. Vucetich, and C. Packer. 2012. Nonlinear effects of group size on the success of wolves hunting elk. Behavioral Ecology 23:75-82

Mace, R. D., J. S. Waller, T. L. Manley, K. Ake, and W. T. Wittinger. 1999. Landscape evaluation of grizzly bear habitat in western Montana. Conservation Biology 13:367-377.

Manly, B. F. J., L. L. McDonald, and D. L. Thomas. 1993. Resource selection by animals. Chapman and Hall, New York, NY.

Martin, B., R. Edward, and A. Jones. 1999. Mapping a future for wolves in the southern Rockies. Southern Rockies Wolf Tracks (The newsletter of Sinapu) 7(2):1-12.

Martinez-Meyer, E., A. T. Peterson, J. L Servin, and L. F. Kiff. 2006. Ecological niche modelling and prioritizing areas for species reintroductions. Oryx 40:411-418.

Martínez-Gutiérrez, Patricia Guadalupe. 2007. Detección de áreas potenciales para la reintroducción del lobo mexicano (Canis lupus baileyi) en México. Master's thesis, Xalapa, Veracruz, México.

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

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

Mech, D., and L. Boitani, editors. 2003. Wolves: Behavior, Ecology, Conservation. University of Chicago Press, Chicago, Illinois.

Mech, L. D. 2004. Is climate change affecting wolf populations in the High Arctic? Climate Change 67:87?93. Mech, L. D. 2011. The scientific classification of wolves: Canis lupus soupus. International Wolf 21:4?7.

Mech, L. D., and L. Boitani. 2003. Wolf social ecology. Pages 1-34 in L. D. Mech and L. Boitani, eds. Wolves: behavior, ecology, and conservation. University of Chicago Press, Chicago, Illinois. 448 pp.

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

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

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

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

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

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

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

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

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

Mech, L.D., S.M. Goyal, W.J. Paul, and W.E. Newton. 2008. Demographic effects of canine parvovirus on a free-ranging population over 30 years. Journal of Wildlife Diseases 44(4): 824-836.

Mech., L. D. 2011. The scientific classification of wolves: Canis lupus soupus. International Wolf 21:4-7.

Mercer, W.W., Tenpas, R.J., William, J.E., Russell, L.L., Gustafson, K. L. (2008a) Declaration of L. David Mech, Defenders of Wildlife et al. v. H. Dale Hall (U.S. Fish & Wildlife Service Director) and Dirk Kempthorne (Secretary of the Interior), Case No. cv-08-56-M-DWM.

Merkle, J. A., P. R. Krausman, D. W. Stark, J. K. Oakleaf, and W. B. Ballard. 2009a. Summer diet of the Mexican gray wolf (Canis lupus baileyi). The Southwestern Naturalist 54:480-485.

Merkle, J.A., D.R. Stahler, and D.W. Smith. 2009b. Interference competition between gray wolves and coyotes in Yellowstone National Park. Canadian Journal of Zoology 87:56-63.

Merrill, E. H., M. K. Bramble-Brodahl, R. W. Marrs, and M. S. Boyce. 1993. Estimation of green herbaceous phytomass from Landsat MSS data in Yellowstone National Park. Journal of Range Management 46:151-157.

Merrill, S., and L. D. Mech. 2000. Details of extensive movements by Minnestora wolves (Canis lupus). American Midland Naturalist 144:428?433.

Merrill, T., D. J. Mattson, R. G. Wright, and H. B. Quigley. 1999. Defining landscapes suitable for restoration of grizzly bears (Ursus arctos) in Idaho. Biological Conservation 87:231-248.

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

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

Mesta, R. 1996. Establishment of a nonessential experimental population of California condors in northern Arizona. Federal Register 61:54044-54060.

Metz, M.C, D.W. Smith, J.A. Vucetich, D.R. Stahler, and R.O Peterson. 2012. Seasonal patterns of predation for gray wolves in the multi-prey system of Yellowstone National Park. Journal of Animal Ecology.

Mexican Wolf SSP Management Group. 2009. Mexican grey wolf husbandry manual: guidelines for captive management. Wild Canid Survival and Research Center, Eureka, Missouri U.S.A. 166pp.

Mills, L. S., and F. W. Allendorf. 1996. The One-Migrant-per-Generation Rule in Consenation and Management. Conservation Biology 6:1509-1518.

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

Milner, J.M., Nilsen, E.B. & Andreassen, H.P. (2007) Demographic side effects of selective hunting in ungulates and carnivores. Conservation Biology 21, 36–47.

Mladenoff, D. J., and T. A. Sickley. 1999. Assessing potential gray wolf restoration in the northeastern United States: a spatial prediction of favorable habitat and potential population levels. Journal of Wildlife Management 62:1-10.

Mladenoff, D. J., R. G. Haight, T. A. Sickley, and A. P. Wydeven. 1997. Causes and implications of species restoration in altered ecosystems: a spatial landscape projection of wolf population recovery. BioScience 47:21-31.

Mladenoff, D. J., T. A. Sickley, and A. P. Wydeven. 1999. Predicting gray wolf landscape recolonization: logistic regression models vs. new field data. Ecological Applications 9:37-44.

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

Mladenoff, D. J., M. K. Clayton, S. D. Pratt , T. A. Sickley, and A. P. Wydeven. 2009. Change in Occupied Wolf Habitat in the Northern Great Lakes Region. Pages 119-138 in A.P. Wydeven et al. (eds.), Recovery of Gray Wolves in the Great Lakes Region of the United States. Springer, NY.

Moctezuma-Orozco, O., H. Coronel-Arellano, A. González-Bernal, N. E. Lara-Díaz, C. A. López-González, H. Caballero Quiroz, F. García-Durazo, D. Zamora-Barcenas, G. Carreón Arroyo y J. C. Gutiérrez Bravo. 2010. Reporte Final para la CONABIO del Proyecto "Reintroducción del Lobo Mexicano (Canis lupus baileyi) en la Sierra Madre Occidental, México". Naturalia A. C.

Murphy, D. D., and B. R. Noon. 1992. Integrating scientific methods with habitat planning: reserve design for northern spotted owls. Ecological Applications 2: 3-17.

Murray, D. L., D. W. Smith, E. E. Bangs, C. Mack, J. K. Oakleaf, J. Fontaine, D. Boyd, M. Jiminez, C. Niemeyer, T. J. Meier, D. Stahler, J. Holyan,V. J. Asher. 2010. Death from anthropogenic causes is partially compensatory in recoveringwolf populations. Biological Conservation 143:2514–2524.

Nalleli E. Lara-Díaz1, Helí Coronel-Arellano2, Alejandro González-Bernal2,Carmina Gutiérrez-González2 y Carlos Alberto López-González. 2011. Abundancia y densidad de venado cola blanca (Odocoileus virginianus couesi) en Sierra de San Luis, Sonora, México. Therya 2(3): 00:00.

Nelson, E. W., and E. A. Goldman. 1929. A new wolf from New Mexico. Journal of Mammalogy 10:165-166.

Nielsen, J. L., J. M. Scott, and J. L. Aycrigg. 2001. Letter to the editor. Endangered species and peripheral populations: cause for conservation. Endangered Species Update 18:193?194.

Nowak, R. M. 1978. Reclassification of the gray wolf in the United States and Mexico, with determination of critical habitat in Michigan and Minnesota. Federal Register 43:9607-9615.

Nowak, R. M. 1979. North American quaternary Canis. Monograph No. 6. Museuam of Natural Hisotry, Universty of Kansas, Lawrence. 154 pp.

Nowak, R. M. 1986. Memorandum dated July 15, 1986 to J. Johnson, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Nowak, R. M. 1995. Another look at wolf taxonomy. Pages 375-397 in L. N. Carbyn, S. H. Fritts, and D. R. Seip, eds. Ecology and conservation of wolves in a changing world. Occasional Publication No 35, Canadian Circumpolar Institute, Edmonton, Alberta. 642 pp.

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

Nuttle, T., R. J. Hobbs, V. M. Temperton, and S. Halle. 2004. Assembly rules and ecosystem restoration: where to from here? Pages 410?421 in V. M. Temperton, R. J. Hobbs, T. Nuttle, and S. Halle (eds.), Assembly rules and restoration ecology: bridging the gap between theory and practice. Washington, D. C.: Island Press.

Oakleaf, J. et al. In prep. Demographic analysis of Blue Range Mexican wolf population.

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

Orr, D. W. 2010. Down to the wire: confronting climate collapse. Oxford University Press, New York. 261 pp. Parsons, D. R. 1996. Case study: the Mexican wolf. New Mexico Journal of Science 36:101?123.

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

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

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

Palacio-Prieto, J. L., G. Bocco, and 14 others. 2000. La condición actual de los recursos forestales en México: resultados del Inventario Forestal Nacional 2000. Investigaciones Geográphicas (UNAM) 43:183-203.

Palstra, F. P., and D. E. Ruzzante. 2008. Genetic estimates of contemporary effective population size: what can they tell us about the importance of genetic stochasticity for wild population persistence? Molecular Ecology 17:3428–3447.

Paquet, P. C, J. Wierzchowski, and C. Callaghan. 1996. Effects of human activity on gray wolves in the Bow River Valley, Banff National Park, Alberta. Chapter 7 in J. Green, C. Pacas, S. Bayley, and L. Cornwell, editors. A cumulative effects assessment and futures outlook for the Banff Bow Valley. Prepared for the Banff Bow Valley Study, Department of Canadian Heritage, Ottawa, Ontario.

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

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

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

Parsons, D.R., and J.E. Nicholopoulos. 1995. Status of the Mexican wolf recovery program in the United States. Pages 141-146 in Carbyn, L.N., S.H. Fritts, and D.R. Seip, editors. Ecology and conservation of wolves in a changing world. Occasional Publication No. 35. Canadian Circumpolar Institute, University of Alberta, Edmonton, Alberta, Canada.

Patterson, B. R., and D. L. Murray. 2008. Flawed population viability analysis can result in misleading population assessment: a case study for wolves in Algonquin Park, Canada. Biological Conservation 141:669-680.

Pauli, J.N. & Buskirk, S.W. (2007) Risk-disturbance overrides density dependence in a hunted colonial rodent, the black-tailed prairie dog, Cynomys ludovicianus. Journal of Animal Ecology 44, 1219–1230.

Pearson RG, Dawson TP. 2003. Predicting the impacts of climate change on the distribution of species: Are bioclimate envelope models useful? Global Ecol. Biogeog. 12:361–71

Pearson, R. 2011. Driven to extinction: the impact of climate change on biodiversity. American Museum of Natural History, Sterling Publishing, New York. 263 pp.

Peters, R. L., and T. E. Lovejoy (editors). 1992. Global warming and biological diversity. Yale University Press, New Haven, Connecticut. 386 pp.

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

Peterson, A. T., M. A. Ortega-Huerta, J. Bartley, V. Sánchez-Cordero, J. Soberón, R. H. Buddemeier, D. R. B. Stockwell. 2002. Future projections for Mexican faunas under global climate change scenarios. Nature 416: 626–629.

Peterson, R. O., N. J. Thomas, J. M. Thurber, and J. a. Vucetich, and T. E. Waite. 1998. Population limitation and the wolves of Isle Royale. Journal of Mammalogy 79:828?841.

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

Phillips, M. K., N. Fascione, P. Miller, and O. Byers. 2000. Wolves in the Southern Rockies: a population and habitat viability assessement. Final report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, Minnesota. 111 pp.

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

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

Pletscher, D. H., R. R. Ream, D. K. Boyd, M. W. Fairchild, and K. E. Kunkel. 1997. Population dynamics of a recolonizing wolf population. Journal of Wildlife Management 61:459-465.

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

Raffensperger, C. & Tickner, J. (1999). Protecting Public Health and the Environment: Implementing The Precautionary Principle, Island Press, Washington, D.C.

Ralls, K., J. D. Ballou, and A. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. Conservation Biology 2:185-193.

Ream, R. R., M. W. Fairchild, D. K. Boyd, and D. H. Pletscher. 1991. Population dynamics and home range changes in a colonizing wolf population. Pages 349-366 in R. B. Keiter and M. S. Boyce, editors. The greater Yellowstone ecosystem: redefining America's wilderness heritage. Yale University Press, New Haven, Connecticut.

Redford, K. H., G. Amato, J. Baillie, P. Beldomenico, E. L. Bennett, N. Clum, R. Cook, G. Fonseca, S. Hedges, F. Launay, S. Lieberman, G. M. Mace, A. Murayama, A. Putnam, J. G. Robinson, H. Rosenbaum, E. W. Sanderson, S. N. Stuart, P. Thomas, and J. Thorbjarnarson. 2011. What does it mean to successfully conserve a (vertebrate) species? Bioscience 61:39-48.

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

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

Regan, H.M., Colyvan, M. & Burgman, M.A. (2002) A taxonomy and treatment of uncertainty for ecology and conservation biology. Ecological Application 12, 618-628.

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

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

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

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

Rolland, V., Hostetler, J. A., Hines T. C., Percival, H. F. & Oli, M.K. (2010) Impact of harvest on survival of a heavily hunted game bird population. Wildlife Research 37, 392-400.

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

Roy, M. S., E. Geffen, D. Ostrander, and R. K. Wayne. 1994. Patterns of differentiation and hybridization in North American wolflike canids, revealed by analysis of microsatellite loci. Molecular Biology and Evolution 11:533?570.

Räikkonen, J., J. A. Vucetich, R. O. Peterson, and M. P. Nelson. 2009. Congenital bone deformities and the inbred wolves (Canis lupus) of Isle Royale. Biological Conservation 142:1025-1031.

Räikkönen, J., A. Bignert, P. Mortensen, and B. Fernholm. 2006. Congenital defects in a highly inbred wild wolf population (Canis lupus). Mammalian Biology. 71:65–73.

Robinson, M.R. 2005. Predatory bureaucracy: the extermination of wolves and transformation of the west. University Press of Colorado, Boulder, CO.

Russo, J.P. 1964. The Kaibab North Deer Herd—Its History, Problems and Manage¬ment: A Research and Management Study. Wildlife Bulletin No. 7. Arizona Game and Fish Department: Phoenix, Arizona.

Saccheri, I. J., P. M. Brakefield. 2002. Rapid spread of immigrant genomes into inbred populations. Proceedings of the Royal Society B 269:1073-1078.

Sánchez, N., and J. A. Guevara. 2006. Evaluación del potencial ecológico del noreste de México para la reintroducción del lobo mexicano (Canis lupus baileyi). Taller de reintroducción del lobo mexicano (Canis lupus baileyi) en México. Libro Breve. CBSG (IUCN/SSC), Puebla.

Sandercock B. K., Nilsen E.B., Broseth H. & Pedersen H.C. (2011) Is hunting mortality additive or compensatory to natural mortality? Effects of experimental harvest on the survival and cause-specific mortality of willow ptarmigan, Journal of Animal Ecology 80, 244-258.

Schneider, S. H., T. L. Root (editors). 2002. Wildlife Responses to climate change: North American case studies. Island Press, Washington, D.C. 437 pp.

Schumaker, N. H. 1998. A user's guide to the PATCH model. EPA/600/R-98/135. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon.

Schwartz, C. C., M. A. Haroldson, G. C. White. 2010. Hazards Affecting Grizzly Bear Survival in the Greater Yellowstone Ecosystem. Journal of Wildlife Management 74(4):654-667.

Schwarz, G. 1978. Estimating the dimension of a model. Annals of Statistics 6:461-464.

Scudday, J. F. 1977. The Mexican gray wolf in Texas. Unpublished typescript. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Scudday, J. F. 1972. Two recent records of gray wolves in west Texas. Journal of Mammalogy 53:598.

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

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

Sedinger J. S., White G. C., Espinosa, S., Parteed, E.T. & Braun, C.E. (2010) Assessing compensatory versus additive harvest mortality: an example using greater sage-grouse. Journal of Wildlife Management 74, 326-332

SEMARNAT. 2000. Mexican wolf (Canis lupus baileyi) recovery project (Proyecto de recuperación del Lobo Mexicano). SEMARNAT, Mexico, D.F.

Servín Martínez, J. I. 2007. Distribución histórica, prospección actual y áreas potenciales para reintroducir lobo mexicano (Canis lupus baileyi) en Durango, sur de la Sierra Madre

Occidental, México. Universidad Juárez del Estado de Durango. Informe final SNIB-CONABIO proyecto No. BE029. México D.F.

Servín, J. 1986. Estudio para la recuperación del lobo mexicano Canis lupus baileyi en el estado de Durango, II Etapa. Informe Técnico, Instituto de Ecología-SEDUE. pp. 41.

Servín, J. 1996. Prospección y búsqueda del lobo mexicano (Canis lupus baileyi) en el estado de Durango. Informe Técnico, Instituto de Ecología-CONABIO. 31 pp.

Servín, J., Enrique Martínez-Meyer, and T. A. Peterson. 2003. Sobre la distribucion historica del lobo mexicano (Canis lupus baileyi) y un analisis del paisaje regional para reintroducirlo en mexico. Unpublished report, 8 pp.

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

Shaffer, M. L. 1987. Minimum viable populations: coping with uncertainty. Pages 69-86 in M. E. Soulé, editor. Viable populations for conservation. Cambridge University Press, Cambridge, UK.

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

Shigesada, N., and K. Kawasaki. 1997. Biological invasions: theory and practice. Oxford series in ecology and evolution. Oxford University Press, Oxford, United Kingdom.

Shinneman, D., R. McClellan, and R. Smith. 2000. The state of the southern Rockies ecoregion. The Southern Rockies Ecosystem Project, Nederland, Colorado.

Siminski, D. P. 1992. The Mexican wolf recovery effort. Pp 300-307 in AAZPA regional conference proceedings.

Siminski, D. P. 2006. Mexican Wolf (Canis Lupus Baileyi): International Studbook. Living Desert Museum, Palm Desert, CA.

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

Siminski, D.P. 2011. Mexican Wolf, Canis lupus baileyi, international studbook, 2011. The Living Desert, Palm Desert, California, U.S.A. 119pp.

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

Siminski, D.P. and E.M. Spevak. 2008. Mexican wolf (Canis lupus baileyi) species survival plan: population analysis and breeding plan. Technical Report. The Living Desert, Palm Desert, California, USA.

Siminski, P. and E. Spevak. 2011. Population analysis and breeding and transfer plan: Mexican wolf Species Survival Plan yellow program. Association of Zoos and Aquariums, Silver Spring, Maryland U.S.A. 82pp.

Singleton, P.H. 1995. Winter habitat selection by wolves in the North Fork of the Flathead River Basin, Montana and British Columbia. M.S. thesis. University of Montana, Missoula.

Smith, D.W., T.D. Drummer, K.M. Murphy, D.S. Guernsey, and S.B. Evans. 2004. Winter prey selection and estimation of wolf kill rates in Yellowstone National Park, 1995-2000. Journal of Wildlife Management 68:153-168.

Smith, D. W., and E. Almberg. 2007. Wolf diseases in Yellowstone National Park. Yellowstone Science 15:17-19.

Smith, D.W. and E.E. Bangs. 2009. Reintroduction of wolves to Yellowstone National Park: History, Values and ecosystem restoration. In: Reintroduction of Top-order Predators. Editors M. Hayward and M. Somers. Wiley-Blackwell.

Smith, D.W., E. E. Bangs, C. Mack, J. Oakleaf, J. Fontaine, D. Boyd, M. Jiminez, D. Pletscher, C. Niemeyer, T. J. Meier, D. Stahler, V. Asher, and D. L. Murray. 2010. Survival of colonizing wolves in the northern Rocky Mountains of the United States 1982–2004. Journal of Wildlife Management 74:620-634.

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

Snyder, N, and H. Snyder. 2000. The California condor: a saga of natural history and conservation. Academic Press, San Diego, California.

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

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

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

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

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

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

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

Southern Rockies Ecosystem Project. 2000. Summary of base data and landscape variables for wolf habitat suitability on the Vermejo Park Ranch and surrounding areas. A Report to the Turner Endangered Species Fund. Southern Rockies Ecosystem Project, Nederland, Colorado. 37 pp (plus figures).

Sparkman AM, Waits LP, Murray DL. 2011. Social and Demographic Effects of Anthropogenic Mortality: A Test of the Compensatory Mortality Hypothesis in the Red Wolf. PLoS ONE 6(6): e20868.

Stockwell, D. R. B. and D. Peters. 1999. The GARP modeling system: problems and solutions to automated spatial prediction. International Journal of Geographic Information Science 13:143-158.

Sutherland, W.J. (2001) Sustainable exploitation: a review of principles and methods. Wildlife Biology 7, 131-140.

Svancara, L. K., R. Brannon, J. M. Scott, C. R. Groves, R. F. Noss, R. L. Pressey. 2005. Policy-driven versus evidence-based conservation: A review of political targets and biological needs. BioScience 55: 989–995.

Sánchez, N., and J. A. Guevara. 2006. Evaluación del potencial ecológico del noreste de México para la reintroducción del lobo mexicano (Canis lupus baileyi). Taller de reintroducción del lobo mexicano (Canis lupus baileyi) en México. Libro Breve. CBSG (IUCN/SSC), Puebla.

Tallmon, D. A., G. Luikart, R. S. Waples. 2004. The alluring simplicity and complex reality of genetic rescue. Trends in Ecology and Evolution 19:489 – 496.

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

Theobald, D.M., H. Gosnell, and W.E. Riebsame. 1996. Land use and landscape change in the Colorado mountains II: a case study of the East River Valley, Colorado. Mountain Research and Development 16(4): 407-418.

Theobold, D. M. 2000. Fragmentation by inholdings and exurban development. Pages 155-174 in R. L. Knight, F. W. Smith, S. W. Buskirk, W. H. Romme, and W. L. Baker, editors. Forest fragmentation in the southern Rocky Mountains. University Press of Colorado, Boulder, Colorado.

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

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

Traill, L. W., B. W. Brook, R. R. Frankham, C. J. A. Bradshaw. 2010. Pragmatic population viability targets in a rapidly changing world. Biological Conservation 143:28-34.

Traill, L. W., C. J. A. Bradshaw, B. W. Brook. 2007. Minimum viable population size: A meta-analysis of 30 years of published estimates. Biological Conservation 139:159-166.

Truett, J. C., K. Bly-Honness, D. H. Long, and M. K. Phillips. 2006. Habitat restoration and management. Pages 97-110 in J. E. Roelle, B. J. Godbey, and D. E. Biggins, eds. Recovery of the black?footed ferret – progress and continuing challenges. U.S. Geological Survey Scientific Investigations Report 2005?5293. 288 pp

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

U.S. Fish and Wildlife Service [USFWS]. 1982. Mexican wolf recovery plan. U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 103 pp.

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

U.S. Fish and Wildlife Service [USFWS]. 1992. Eastern timber wolf recovery plan. U.S. Fish and Wildlife Service, Fort Snelling, Minnesota.

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

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

U.S. Fish and Wildlife Service [USFWS]. 1995. Mexican wolf recovery plan – draft. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

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

U.S. Fish and Wildlife Service [USFWS]. 2000. Environmental Assessment for the translocation of Mexican wolves throughout the Blue Range Wolf Recovery Area in Arizona and New Mexico. Region 2, Albuquerque, New Mexico, USA.

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

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

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

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

U.S. Fish and Wildlife Service [USFWS]. 2003. Administrative record for the southwestern gray wolf distinct population segment recovery team. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

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

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

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

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

U.S. Fish and Wildlife Service [USFWS]. 2007. Umbrella candidate conservation agreement with assurances between MTFWP and USFWS for westslope cutthroat trout introductions/reintroductions in Montana (as amended August 16, 2007). U.S. Fish and Wildlife Service, Denver, Colorado.

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

U.S. Fish and Wildlife Service [USFWS]. 2009. Mexican gray wolf recovery program website. <http://www.fws.gov/southwest/es/mexicanwolf/>. Accessed March 1, 2008 – April 20, 2009.

U.S. Fish and Wildlife Service [USFWS]. 2009. Final Rule To Identify the Northern Rocky Mountain Population of Gray Wolf as a Distinct Population Segment and To Revise the List of Endangered and Threatened Wildlife Federal Register 74, 15123- 15187 (2nd April 2009).

U.S. Fish and Wildlife Service [USFWS]. 2009. Rocky Mountain Wolf Recovery 2008 Interagency Annual Report. 1-362. USFWS Rocky Mountain Gray Wolf Website. http://www.fws.gov/mountain-prairie/spec ies/mammals/wolf/annualrpt09/index.html.

U.S. Fish and Wildlife Service [USFWS]. 2011. Proposed rule to revise the list of endangered and threatened wildlife for the gray wolf (Canis lupus) in the eastern United States, initiation of status reviews for the gray wolf and the eastern wolf (Canis lycaon). Federal Register 76:26086-26145.

U.S. Fish and Wildlife Service [USFWS]. 2011. Removal of the gray wolf in Wyoming from the federal list of endangered and threatened wildlife and removal of the Wyoming wolf population’s status as an experimental population. Federal Register 76, 61782-61823 (5th October 2011).

U.S. Fish and Wildlife Service [USFWS]. 2012. A review of the third five years of the California condor reintroduction program in the southwest (2007-2011). U.S. Fish and Wildlife Service, Sacramento, California.

Unsworth, R., L. Genova, K. Wallace, and A. Harp. 2005. Mexican wolf Blue Range reintroduction project 5-year review: socioeconomic component. Final Report. Prepared for Division of Economics, U.S. Fish and Wildlife Service, Arlington, Virginia, USA. http://www.fws.gov/southwest/es/mexicanwolf/pdf/MW5YRSocioeconomicsFinal20 051231.pdf

Van Camp, J., and R. Gluckie. 1979. A record long distance move by a wolf. Journal of Mammalogy 60:236.

Vilà, C., A.-K.Sundqvist, Ø. Flagstad, J. Seddon, S. Björnerfeldt, I. Kojola, A. Casulli, H. Sand, P. Wabakken, and H. Ellegren. 2003. Rescue of a severely bottlenecked wolf (Canis lupus) population by a single immigrant. Proceedings of the Royal Society London Biology Series B 270:91–97.

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

Vogelmann, J. E., S. M. Howard, L. Yang, C. R. Larson, B. K. Wylie, and N. Van Driel. 2001. Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources. Photogrammetric Engineering and Remote Sensing 67:650-662.

Vogelmann, J.E., T. Sohl, and S. M. Howard. 1998. Regional characterization of land cover using multiple sources of data. Photogrammetric Engineering & Remote Sensing 64: 45-47.

Vonholdt, B. M., D. R. Stahler, D. W. Smith, D. A. Earl, J. P. Pollinger, and R. K. Wayne. 2008. The genealogy and genetic viability of reintroduced Yellowstone grey wolves. Molecular Ecology 17:252-274.

Vonholdt, B. M., D. R. Stahler, E. E. Bangs, D. W. Smith, M. D. Jimenez, C. M. Mack, C. C. Niemeyer, J. P. Pollinger, and R. K. Wayne. 2010. A novel assessment of population structure and gene flow in grey wolf populations of the Northern Rocky Mountains of the United States. Molecular Ecology 19:4412–4427.

Vonholdt, B. M., J. P. Pollinger, D. A. Earl, J. C. Knowles, A. R. Boyko, H. Parker, E. Geffen, M. Pilot, W. Jedrzejewski, B. Jedrzejewska, V. Sidorovich, C. Greco, E. Randi, M. Musiani, R. Kays, C. D. Bustamante, E. A. Ostrander, J. Novembre, and R. K. Wayne. 2011. A genome-wide perspective on the evolutionary history of enigmatic wolf-like canids. Genome Research 21: 1294-1305 .

Vucetich, J. A. and Waite, T. A. 2000. Is one migrant per generation sufficient for the genetic management of fluctuating populations? Animal Conservation 3: 261–266.

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

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

Vucetich, J.A. & Peterson R.O. 2004. The influence of prey consumption and demographic stochasticity on population growth rate of Isle Royale wolves Canis lupus. Oikos 107, 309-320.

Vucetich, J.A., Smith, D.W. & Stahler, D.R. 2004. Influence of harvest, climate and wolf predation on Yellowstone elk, 1961-2004 . Oikos 111, 259-270.

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

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

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

Wayne, R. K. 1992. On the use of morphological and molecular genetics characters to investigate species status. Conservation Biology 6:590-592.

Wayne, R. K. 1995. Red wolves: to conserve or not to conserve. Canid News (Newsletter of the IUCN/SSC Canid Specialist Group) 3:7-12.

Wayne, R. K., N. Lehman, M. W. Allard, R. L Honeycutt. 1992. Mitochondrial DNA variability of the gray wolf: generic consequences of population decline and habitat fragmentation. Conservation Biology 6:559-569.

Wayne, R. K., N. Lehman, T. K. Fuller. 1995. Conservation genetics of the gray wolf. Pages 399-407 in L. N. Carbyn, S. H. Fritts, and D. R. Seip, eds. Ecology and conservation of wolves in a changing world. Occasional Publication No 35, Canadian Circumpolar Institute, Edmonton, Alberta. 642 pp.

Wayne, R.K., E. Geffen, and C. Vilá. 2004. Population and conservation genetics of canids. Pages 55-84 in Carbyn, L.N., S.H. Fritts, and D.R. Seip, editors. Ecology and conservation of wolves in a changing world. Occasional Publication No. 35. Canadian Circumpolar Institute, University of Alberta, Edmonton, Alberta, Canada

Wayne, R., and P. Hedrick. 2011. Genetics and wolf conservation in the American West: lessons and challenges. Heredity 107:16–19.

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

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

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

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

Weaver J.L., P.C. Paquet, and L.F. Ruggiero. 1996. Resilience and conservation of large carnivores in the Rocky Mountains. Conservation Biology 10: 964-976.

Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. Science 313:940?943

Wharton, S. W., and M. F. Myers. 1997. MTPE EOS data products handbook: Vol. 1. Pub. 902, NASA Goddard Space Flight Center, Greenbelt, MD. 266 pp.

White, J. D., S. W. Running, R. Nemani, R. E. Keane, and K. C. Ryan. 1997. Measurement and remote sensing of LAI in Rocky Mountain montane ecosystems. Canadian Journal of Forest Research 27:1714-1727.

Wiersma, Y. F., and J. Sandlos. 2011. Once there were so many: animals as ecological baselines. Environmental History 16:400?407.

Wikipedia, the free encyclopedia. 2008. Wikipedia website. http://en.wikipedia.org/wiki/Kenton_Joel_Carnegie_wolf_attack#cite_note- paquetreport-0. Accessed April 17, 2008.

Wiles, G., H. Allen, and G. Hayes. 2010. Draft Wolf Conservation and Management Plan for Washington. Washington State Department of Fish and Wildlife, Olympia, WA.

Williams, A.P., C.D. Allen, C.I. Millar, T.W. Swetnam, J. Michaelsen, C.J. Still, and S.W. Leavitt. 2010. Forest responses to increasing aridity and warmth in the southwestern United States. Proceedings of the National Academy of Sciences 107:21289?21294.

Wilmers, C.C., R.L. Crabtree, D.W. Smith, K.M. Murphy, and W.M. Getz. 2003. Trophic facilitation by introduced top predators: grey wolf subsidies to scavengers in Yellowstone National Park. Journal of Animal Ecology 72:909-916.

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

Woodroffe, R., and J. R. Ginsberg. 1998. Edge effects and the extinction of populations inside protected areas. Science 280:2126-2128.

Wyoming Game and Fish Commission. (2011) Wyoming Gray Wolf Management Plan. September 14, 2011. 61 pp.

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

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

INCOMPLETE CITATIONS

{?}U.S. Fish and Wildlife Service [USFWS]. 2003a.

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 Component (ARC)
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

SWDPS Recovery Team	Southwestern Gray Wolf Distinct Population Segment (with emphasis on the Mexican gray wolf, *Canis lupus baileyi*) Recovery Team
USDA-WS	US Department of Agriculture-Animal Plant Health Inspection Service, Wildlife Services
USFWS or Service	US Fish and Wildlife Service
USFS	USDA Forest Service
WMAT	White Mountain Apache Tribe