DRAFT

BIOLOGICAL REPORT for the Mexican wolf (*Canis lupus baileyi*)

U.S. Fish and Wildlife Service
Southwest Region (Region 2)
Albuquerque, New Mexico
2017

ACKNOWLEDGEMENTS

A revision of the 1982 Mexican Wolf Recovery Plan has been a long time in coming, and we are grateful to the many people who have contributed their expertise, perspectives, and dedication to the Mexican wolf recovery effort over the last four decades.

The U.S. Fish and Wildlife Service would like to recognize the participants who attended the series of information gathering workshops held between December 2015 and February 2017 for the development of the biological report and revised recovery plan:

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We are especially grateful to Phil Miller, Kathy Traylor-Holzer, and the Conservation Breeding Specialist Group for conducting population viability modeling for the Mexican wolf and facilitation of the information gathering workshops. Rich Fredrickson also contributed extensively to the current development of the population viability model. We would like to recognize Bob Lacy for extending the capacity of Vortex for the Mexican wolf modeling effort.

We would like to thank Cristian Aguilar-Miguel, Carmen Chávez-García, Alejandro González-Bernal, Zaira Y. González-Saucedo, Nalleli E. Lara-Díaz, Carlos López-González, Enrique Martínez-Meyer, John K. Oakleaf, Jorge Servín, Tyson L. Swetnam, and Julián A. Velasco for their development of a binational Mexican wolf habitat suitability analysis in Mexico and the United States. Arizona Game and Fish Department recognized the significant improvement in GIS data availability in the last few years that provides increasingly consistent data layers between the two countries. We would also like to recognize Carlos Carroll, Carlos López-González, and Mike Phillips for their earlier insights regarding suitable Mexican wolf habitat. Thank you also to Francisco "Paco" Abarca, Jose "Pepe" Bernal, Lizardo Cruz, Monica de la Fuente-Galicia, Fernando Gavito, Jim Heffelfinger, Angelica Narvaez, Peter Siminski, Oscar Ramirez, and Roberto Wolf for their important contributions to a binational recovery effort.

We would also like to thank the Mexican Wolf Recovery Team of 2010-2013, including all members of the Tribal, Stakeholders, Agency Liaisons, and Science and Planning subgroups, as well as the members of the 2003 and 1998 recovery teams. The U.S. Fish and Wildlife Service is indebted to their contributions of time, information, analysis, and deliberative discussion; their work provided a springboard for this biological report and revised recovery plan. Peter Siminski served as team leader for two previous recovery teams, and we are grateful for the leadership he provided.

We are deeply appreciative of the ongoing work of the Mexican Wolf Tribal Working Group, whose members developed the “Tribal Perspectives on Mexican Wolf Recovery” white paper and continue to work with the U.S. Fish and Wildlife Service to ensure the voices of the many tribes of the Southwest Region are heard.

We gratefully acknowledge the continuing engagement of our current and former interagency partners in the reintroduction and recovery effort, including Arizona Game and Fish Department, U.S. Forest Service, White Mountain Apache Tribe, U.S. Department of Agriculture-Wildlife Services, New Mexico Department of Game and Fish, as well as the counties of Gila, Graham, Greenlee, Navajo, and the Eastern Arizona Counties Organization in Arizona and New Mexico. We are grateful for the continuing collaboration with the Comisión Nacional de Áreas Naturales Protegidas (CONANP) and the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) in Mexico, and recognize the contributions of these agencies’ staff and leaders to the Mexican wolf recovery effort.

We owe perhaps our biggest thank you to the binational Mexican Wolf Species Survival Plan breeding facilities of the Association of Zoos and Aquariums, without whom the reintroduction of the Mexican wolf would not be possible. We are grateful for the member institutions and their many staff who maintain these facilities, conduct research and annual reproductive planning, educate the public, and facilitate the transport of captive wolves between facilities and to the wild as needed.

An enourmous thank you is owed to the Interagency Field Team for their tireless effort throughout the years to establish and maintain Mexican wolves on a working landscape. Reintroductions require an extensive group of dedicated personnel to collect data and accomplish the goal of establishing a population. Data for this project has been collected by personnel from the Arizona Game and Fish Department, the New Mexico Department of Game and Fish, the U.S. Fish and Wildlife Service, U.S. Department of Agriculture – Wildlife Services, and the White Mountain Apache Tribe. There are too many employees to list from 1998 – 2016, but we appreciate your efforts and dedication. In particular, Colby Gardner (U.S. Fish and Wildlife Service) assisted with the databases that were required to initially populate the population viability model. A group of dedicated pilots with the Arizona Game and Fish Department have kept many employees safe during flights to collect data. We also appreciate the continued partnership of the U.S. Forest Service in recovery of the Mexican wolf.

Finally, within the U.S. Fish and Wildlife Service, we acknowledge the staff of the Mexican Wolf Recovery Program, Sevilleta National Wildlife Refuge, and our Southwest Region and Mountain-Prairie Region colleagues and leaders for their contributions.

LITERATURE CITATION AND AVAILABILITY

Literature citation should read as follows:
U.S. Fish and Wildlife Service. 2017. Draft Mexican Wolf Biological Report. Region 2, Albuquerque, New Mexico, USA.

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

Copies of the document can also be requested from:

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New Mexico Ecological Services Field Office
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INTRODUCTION TO THE BIOLOGICAL REPORT

This biological report informs the U.S. Fish and Wildlife Service's (Service, we) revision of the 1982 Mexican Wolf Recovery Plan. We are revising the recovery plan to provide an updated strategy to guide Mexican wolf (*Canis lupus baileyi*) conservation efforts. As a supplement to the recovery plan, the biological report enables us to streamline the recovery plan to focus on the statutorily required elements of the Endangered Species Act (Act, or ESA):

- A description of site-specific management actions that may be necessary to achieve the plan's goal for the conservation and survival of the Mexican wolf;
- Objective, measurable criteria which, when met, would result in a determination that the Mexican wolf may be removed from the List of Threatened and Endangered Wildlife and Plants;
- 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.

In this biological report, we briefly describe the biology/ecology of the Mexican wolf, its abundance, distribution and population trends, and stressors to recovery. We then consider the concepts of resiliency, redundancy, and representation as they apply to the recovery of the Mexican wolf. The biological report draws on the substantial amount of information available from the course of our reintroduction effort and in the scientific literature. We cite our existing regulations, annual reports, and related documents when possible rather than providing an exhaustive recounting of all available information.

The biological report contains two appendices, "Population Viability Analysis for the Mexican Wolf (*Canis lupus baileyi*): Integrating Wild and Captive Populations in a Metapopulation Risk Assessment Model for Recovery Planning" (Miller 2017) and "Mexican Wolf Habitat Suitability Analysis in Historical Range in the Southwestern U.S. and Mexico" (Martínez-Meyer et al. 2017). The Vortex report assesses the conditions needed for Mexican wolf populations to maintain long-term viability. The habitat suitability report assesses the current condition of the landscape in portions of Arizona, New Mexico, and Mexico based on habitat features required to sustain Mexican wolf populations. Together, the biological report and its appendices provide a succinct accounting of the best available science to inform our understanding of the current and future viability of the Mexican wolf, and therefore serve as a foundation for our strategy to recover the Mexican wolf.

Our development of a biological report is an interim approach as we transition to using a species status assessment as the standard format to analyze species and make decisions under the Act. We intend for species biological reports to support all functions of the Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery. For the Mexican wolf, which is already listed, we have developed a biological report as part of the ongoing recovery process.

The biological report, the revised recovery plan, and a separate detailed implementation strategy provide a three-part operational vision for Mexican wolf recovery. The biological report and implementation strategy will be updated as new information is gained or annual implementation progress informs adaptation of our management actions over time. The recovery plan is broader in its scope, providing an overarching strategy, objective and measurable criteria, and actions that we intend will remain valid, potentially for the entire course of the recovery process. In addition, tribes and pueblos in the Southwest have developed a white paper to describe the ecological, cultural, and logistical aspects of Mexican wolf recovery to their communities, "Tribal Perspectives on Mexican Wolf Recovery." This report is available on our website, at: https://www.fws.gov/southwest/es/mexicanwolf/MWRP.cfm.

BRIEF DESCRIPTION OF MEXICAN WOLVES IN CAPTIVITY AND THE WILD

Recovery efforts for the Mexican wolf have been underway in the United States and Mexico since the late 1970's. Both countries are working to reestablish Mexican wolves in the wild and are involved in maintaining a binational captive population of Mexican wolves.

In the United States, a single population of at least 113 Mexican wolves inhabits portions of Arizona and New Mexico in an area designated as the Mexican Wolf Experimental Population Area (MWEPA) (U.S. Fish and Wildlife Service [USFWS] 2017a) (Figure 1). Mexican wolves are not present in the wild in the United States outside of the MWEPA. The Service began releasing Mexican wolves from captivity into the MWEPA in 1998, marking the first reintroduction of the Mexican wolf since their extirpation in the late 1970's. The Service is now focused on inserting gene diversity from the captive population into the growing wild population. Additional detailed history of the reintroduction of Mexican wolves in the MWEPA is available in our "Final Environment Impact Statement for the Proposed Revision to the Regulations for the Nonessential Experimental Population of the Mexican Wolf" (USFWS 2014) and in annual progress reports. (These documents are available online at: https://www.fws.gov/southwest/es/mexicanwolf/).

Figure 1. Mexican Wolf Experimental Population Area in the Arizona and New Mexico, United States (U.S. Fish and Wildlife Service files).

Mexico began reestablishing a population of Mexican wolves in the Sierra Madre Occidental Mountains in 2011 (Siminski and Spevak 2016). As of April 2017, approximately 28 wolves inhabit the northern portion of these mountains in the state of Chihuahua (Garcia Chavez et al. 2017) (Figure 2). Natural reproduction was documented in 2014, 2015, and 2016 (personal communication with Dr. López-González, Universidad Autónoma de Querétaro, March 13, 2017). Additional detailed information about the status of Mexican wolves in Mexico is available in updates from the Comisión Nacional de Áreas Naturales Protegidas (available online at http://procer.conanp.gob.mx/noticias.html).

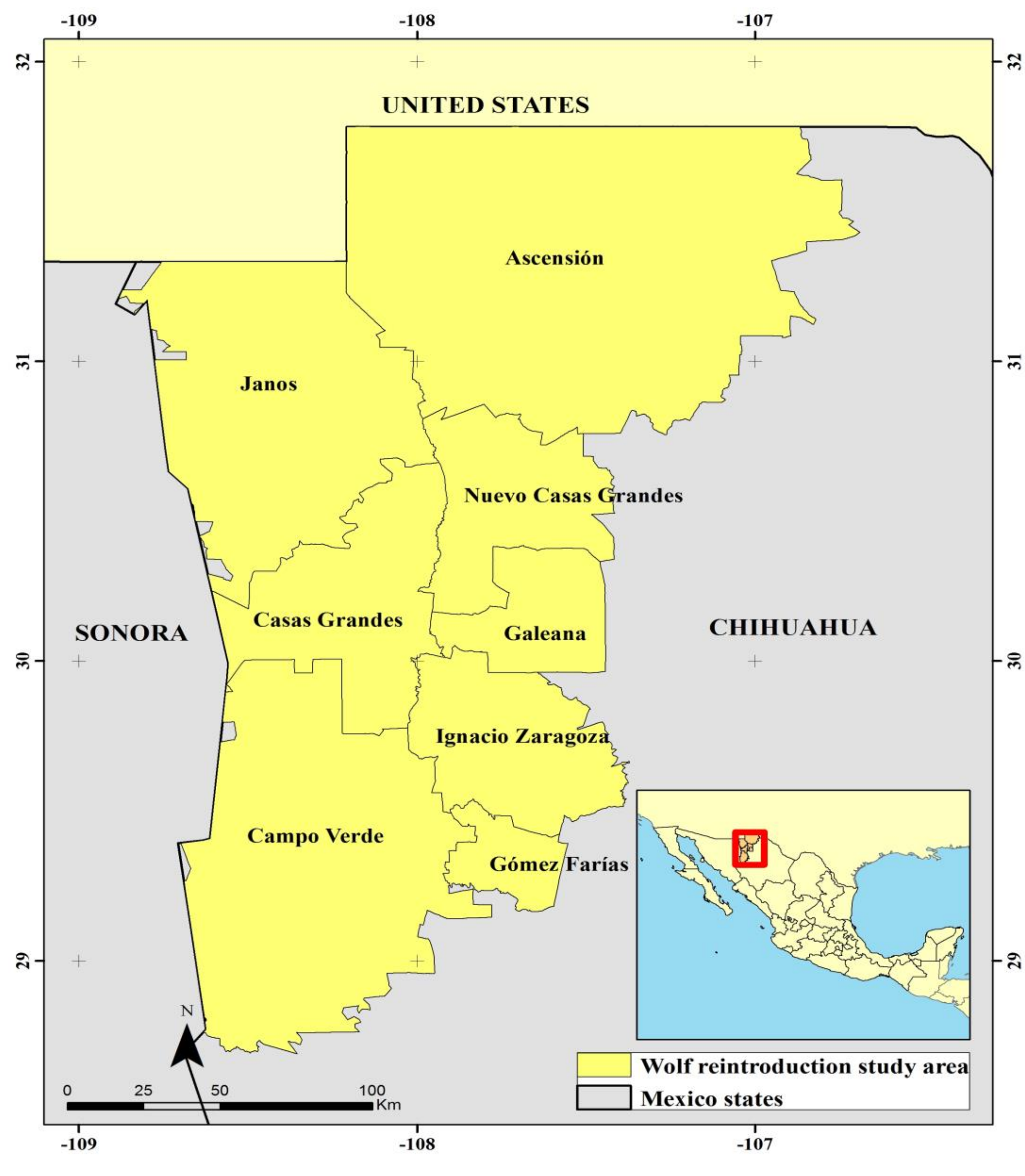

Figure 2. Approximate range of Mexican wolves in Mexico as of March 2017 (map provided by Dr. López-González, Universidad Autónoma de Querétaro, March 13, 2017). The names on the map within the yellow polygon represent municipalities within the state of Chihuahua.

The Mexican wolf captive population is managed under the Mexican Wolf Species Survival Plan (SSP), administered by the Association of Zoos and Aquariums. The Mexican wolf SSP is a binational program whose primary purpose is to produce Mexican wolves for reintroduction in the United States and Mexico, and to conduct public education and research. The captive population is the sole source of Mexican wolves available to reestablish the species in the wild and is therefore an essential component of the Mexican wolf recovery effort. The Mexican wolf captive breeding program was initiated in 1977 to 1980 with the capture of the last remaining Mexican wolves in the wild in Mexico and the subsequent addition of several wolves already in captivity, for a total of seven unrelated "founders." This is a small number of founders compared with many species recovery efforts and presents challenges to the recovery of the Mexican wolf. The founding wolves represented three family groups referred to as the McBride (originally referred to as Certified), Aragon, and Ghost Ranch lineages (Siminski and Spevak 2016). Each of the animals from these lineages has been confirmed to be pure Mexican wolves (García-Moreno et al. 1996). All Mexican wolves alive today in captivity or the wild are descendants of the seven founders.

The SSP strives to maintain at least 240 Mexican wolves in captivity. As of October 21, 2016, the binational captive program houses 251 wolves in 51 institutions (Siminski and Spevak 2016) (Figure 3). Although the captive population is spread over many institutions in two countries, annual reproductive planning and transportation of wolves between facilities to facilitate breeding results in management of the animals as a single population. Wolves that are genetically well-represented in the captive populations can be selected for release to the wild (Siminski and Spevak 2016). The SSP maintains a pedigree of Mexican wolves in captivity and in the wild, although maintaining the wild pedigree will become more challenging over time as the populations in the United States and Mexico grow and it becomes more difficult to track the parentage of each individual wolf.

Figure 3. General locations of Mexican wolf captive breeding facilities in the U.S. and Mexico (U.S. Fish and Widlife Service files).

LEGAL AND HISTORICAL CONTEXT

Legal Status of the Species

The Mexican wolf, *C.l. baileyi*, is listed as an endangered subspecies under the Act. The Service originally listed the Mexican wolf as an endangered subspecies in 1976, but subsequently subsumed it into a rangewide listing for the gray wolf species (41 FR 17736 April 28, 1976; 43 FR 9607, March 9, 1978). In 2015 we finalized a rule to separate the Mexican wolf subspecies from the gray wolf listing, retaining its status as endangered (80 FR 2488, January 16, 2015). Critical habitat has not been designated for the Mexican wolf.

The Service designated a Mexican Wolf nonessential experimental population under section 10j of the Act in 1998, which was revised in 2015 (80 FR 2512, January 16, 2015). Mexican wolves' status is dependent on their location: Mexican wolves within the MWEPA boundaries are considered part of the nonessential experimental population; Mexican wolves outside of the MWEPA boundary are considered endangered. There are currently no known Mexican wolves outside of the MWEPA boundaries in the United States. The protections and prohibitions for the nonessential experimental population of Mexican wolves are provided in our rule, "Revisions to the Regulations for the Nonessential Experimental Population of Mexican wolves" (80 FR 2512, January 16, 2015; available on our website at https://www.fws.gov/southwest/es/mexicanwolf).

The Mexican wolf is protected under State wildlife statutes in the Southwest as the gray wolf, and by federal regulation as a subspecies in Mexico. In Arizona, the gray wolf is identified as a Species of Greatest Conservation Need (Arizona Game and Fish Department 2012). The gray wolf is listed as endangered in New Mexico (Wildlife Conservation Act, 17-2-37 through 17-2-46 NMSA 1978; List of Treatened and Endnagered Species, 19.33.6 NMAC 1978) and Texas (Texas Statute 31 T.A.P). In Mexico, the Mexican wolf is assigned a status of "probably extinct in the wild" under Mexican law (Norma Oficial Mexicana NOM-059- SEMARNAT-2010) (Secretaría de Medio Ambiente y Recursos Naturales [SEMARNAT; Federal Ministry of the Environment and Natural Resource] 2010). The Norma Oficial Mexicana NOM-059-SEMARNAT-2010 provides the regulatory framework for assessing and categorizing extinction risk levels, although the Mexican wolf has not been assessed because prior to the initiation of the reintroduction effort in 2011, the existence of live individuals in the wild had not been affirmed.

Historical Causes of Decline

When the Mexican wolf was listed as endangered under the Act in 1976, no wild populations were known to remain in the United States, and only small pockets of wolves persisted in Mexico, resulting in a complete contraction of the historical range of the Mexican wolf (Brown 1988, and see USFWS 2010). Reintroduction efforts in the United States and Mexico have begun to restore the Mexican wolf to portions of its former range in Arizona, New Mexico, and Mexico.

The near extinction of the Mexican wolf was the result of government and private campaigns to reduce predator populations during the late 1800's- to mid- 1900's due in part to conflict with the expanding ranching industry (Brown 1988). While we know that efforts to eradicate Mexican wolves were effective, we do not know how many wolves were on the landscape preceeding their rapid decline. Some trapping records, anecdotal evidence, and rough population estimates are available from the early 1900s, but they do not provide a rigorous estimate of population size of

Mexican wolves in the United States or Mexico. In New Mexico, a statewide carrying capacity (potential habitat) of about 1,500 gray wolves was hypothesized by Bednarz (1988), with an estimate of 480 to 1,030 wolves present in 1915. We hypothesize, based on this information, that across the southwestern United States and Mexico Mexican wolves numbered in the thousands in multiple populations.

SPECIES DESCRIPTION AND NEEDS

Taxonomy and Description

The Mexican wolf, *C. l. baileyi*, is a subspecies of gray wolf (Nelson and Goldman 1929) and member of the dog family *(Canidae: Order Carnivora).* The genus *Canis* also includes the red wolf (*C. rufus*), Eastern wolf (*C. lycaon*), dog (*C. familiaris*), coyote (*C. latrans*), several species of jackal (*C. aureus*, *C. mesomelas*, *C. adustus*) and the dingo (*C. dingo*) (Mech 1970). The type locality of *C. l. baileyi* is Colonia Garcia, Chihuahua, Mexico based on a gray wolf 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 (Nelson and Goldman 1929).

Goldman (1944) provided the first comprehensive treatment of North American wolves. Since that time, gray wolf taxonomy has undergone substantial revision related to the grouping of subspecies. Most notably, Nowak (1995) condensed 24 previously recognized North American gray wolf subspecies into five subspecies, including *C.l. baileyi* as one of the remaining five. Gray wolf taxonomy continues to be an unsettled area of scientific inquiry for gray wolves in some parts of North America (e.g., Chambers et al. 2012, vonHoldt et al. 2011). However, the distinctiveness of *C. l. baileyi* and its recognition as a subspecies is resolved and is not at the center of these ongoing discussions.

The uniqueness of the Mexican wolf continues to be supported by both morphometric (Bogan and Mehlhop 1983, Hoffmeister 1986, Nowak 2003) and genetic (Chambers et al. 2012, Garcia-Moreno et al. 1996, Hedrick et al. 1997, Leonard et al. 2005, VonHoldt et al. 2011) evidence. Most recently, Cronin et al. (2014) challenged the subspecies concept for North American wolves, including the Mexican wolf, based on their interpretation of other authors work (most notably Leonard et al. 2005 relative to mtDNA monophyly); however there is broad concurrence in the scientific literature that the Mexican wolf is differentiated from other gray wolves by multiple morphological and genetic markers. Further, Leonard et al. (2005) found that haplotypes associated with the Mexican wolf are related to other haplotypes that have a southerly distribution they identified as a southern clade. A clade is a taxonomic group that includes all individuals that are related and sometimes assumed to have descended from a common ancestor. The Service continues to recognize the Mexican wolf as a subspecies of gray wolf (80 FR 2488-2567, January 16, 2015). Limited discussion of the historical range of the Mexican wolf is ongoing in the scientific literature (see below).

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 1988). Females are typically smaller than males in weight and length. Mexican wolves are typically a patchy black, brown to cinnamon, and cream color, with primarily light underparts (Brown 1988); solid black or white Mexican wolves have never been documented as seen in other North American gray wolves (Figure 4).

Figure 4. Mexican wolf (credit: U.S. Fish and Wildlife Service).

Distribution

As explained by Heffelfinger et al. (2017), when the Mexican wolf was more common on the landscape and originally described in the literature, its range was defined as southern Arizona, southwestern New Mexico, and the Sierra Madre of Mexico south at least to southern Durango (Nelson and Goldman 1929). In the following decades, observers working in this region reaffirmed this geographic range based on body size and skull morphology through first-hand observation and examination of Mexican wolves and specimens (Bailey 1931; Young and Goldman 1944; Hoffmeister 1986; Nowak 1995, 2003, as cited by Heffelfinger et al. 2017). (See above discussion of Taxonomy and our discussion of historical range in our final listing rule "Endangered Status for the Mexican Wolf" (80 FR 2488-2567, January 16, 2015)). The taxonomic issues surrounding the validity of the Mexican wolf subspecies are largely resolved, but there remain some differing opinions in the literature of what areas should be considered for recovery.

Bogan and Mehlhop (1983) analyzed measurements from 253 adult wolf skulls from throughout the Southwest and reported that wolves from northern New Mexico and southern Colorado were distinct from Mexican wolves in southeastern Arizona, southern New Mexico, and Mexico. Specimens from the Mogollon Rim in central Arizona were intermediate between those two forms, with females showing affinity to the larger northern group and males being more similar to Mexican wolves in the south. They recognized the Mogollon Rim as a wide zone of intergradation, but suggested including wolves from this area (*C. l. mogollonensis*) and Texas (*C. l. monstrobalis*) with Mexican wolves. In the 1982 Mexican Wolf Recovery Plan, the Service adopted a historical range for the Mexican wolf based on Bogan and Mehlhop (1983). Subsequently, the Service adopted the historical range proposed by Parsons (1996), a 200-mile northward extension into central New Mexico and east-central Arizona of the historical range of *C.l. baileyi*, based on knowledge of dispersal patterns (USFWS 1996; 63 FR 1752; January 12, 1998) (Figure 5). The Service's adoption of Parsons' (1996) historical range was used to support reintroduction of the Mexican wolf north of *C. l. baileyi*'s range as originally conceived by early accounts (e.g., Nelson and Golman 1929; Young and Goldman 1944; Hall and Kelson 1959, Nowak 1995, 2003, Chambers et al. 2012).

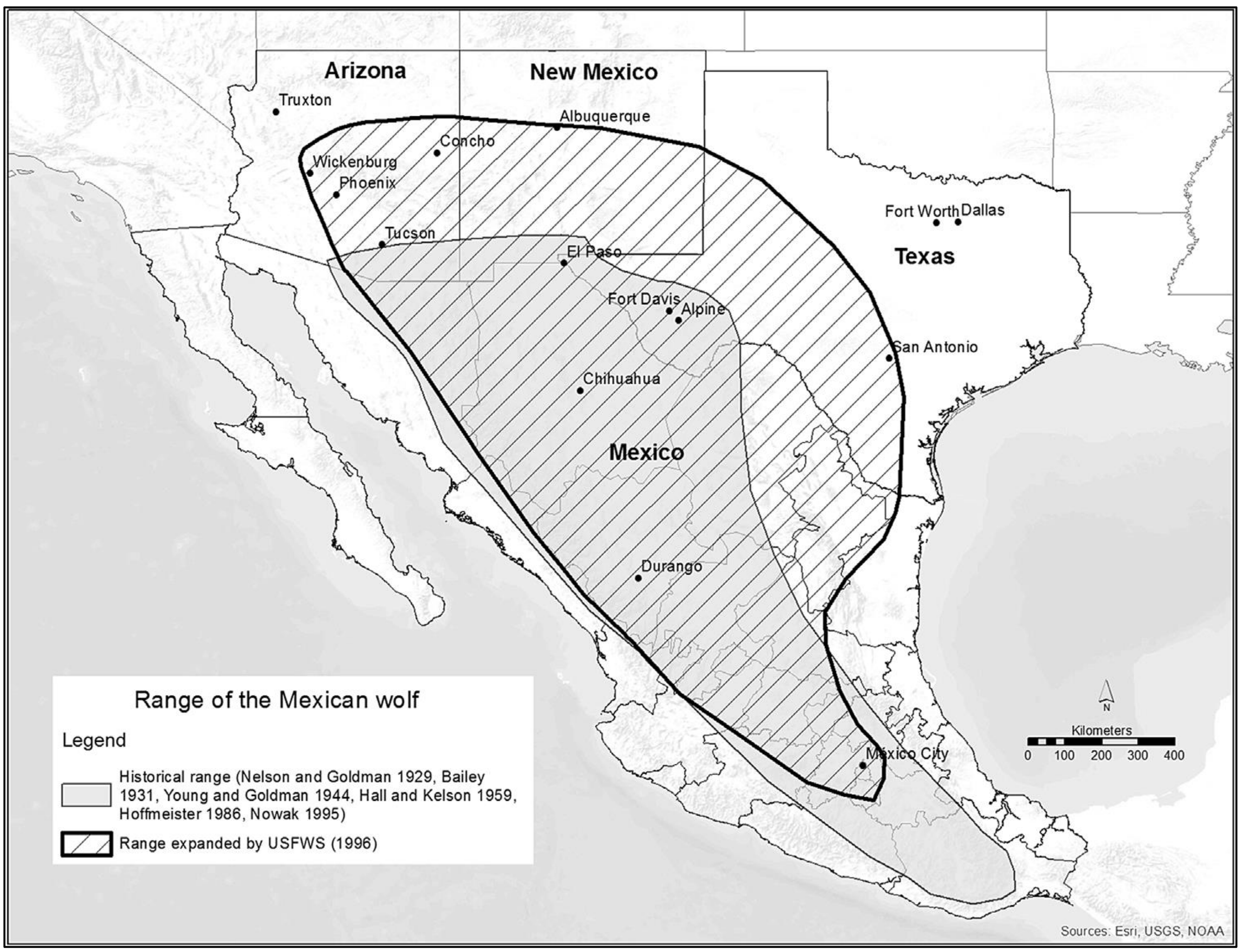

Figure 5. Generalized historical range of the Mexican wolf defined by most authorities compared with the range expanded by Parsons (1996) and adopted by the United States Fish and Wildlife Service (USFWS 1996:1–4) as "probable historic range" (map and title from Heffelfinger et al. 2017).

In recent years, the analysis of molecular markers has led some to suggest the historical range of the Mexican wolf may have extended as far north as Nebraska and northern Utah (Leonard et al.

2005), and as far west as southern California (Hendricks et al. 2015, 2016). Distribution of those molecular markers has led those researchers and others to suggest a larger geographic area could be used for recovery of the Mexican wolf. Heffelfinger et al. (2017) counter that these interpretations and recommendations overstep the power of the studies' limited data sets, inappropriately discount historical accounts of distribution, and conflict with the phylogeographic concordance Mexican wolves share with other southwestern species and subspecies association with the madrean Pine-Oak woodland.

The Service acknowledges that intergradation zones between Mexican wolves and other gray wolf populations likely occurred in central Arizona and New Mexico (Bogan and Mehlhop 1983, Heffelfinger et al. 2017) as incorporated into the historical range expanded by Parsons (1996). The Service continues to recognize the concordance in the scientific literature depicting the Sierra Madre of Mexico and southern Arizona and New Mexico as Mexican wolf core historical range. Further, the Service continues to accept a depiction of historical range as per Parsons (1996) that extends into central New Mexico and Arizona (USFWS 1996). The Service will continue to monitor the scientific literature for exploration of this topic.

Life History

Gray wolves have a relatively simple life history that is well documented in the scientific literature and generally familiar to the public. Published studies specific to the Mexican wolf subspecies are less readily available, but can be inferred from gray wolf information, given the similarity in life history. Our monitoring data from the MWEPA is useful in pointing out Mexican wolf characteristics or needs that may differ from the gray wolf. Although Mexico has not gathered extensive data due to the short timeframe of their reintroduction, we use available information to the extent possible. Because we previously summarized life history information for the gray wolf/Mexican wolf in our Mexican Wolf Conservation Assessment (USFWS 2010), only a brief summary is provided here to highlight the essential needs of the Mexican wolf at the level of the individual animal and the population as they relate to conditions for viability.

Mexican wolves are social animals born into a family unit referred to as a pack. A wolf pack is typically some variation of a mated (or, breeding) pair and their offspring, sometimes of varying ages (Mech and Boitani 2003). Pack size in the MWEPA between 1998 and 2016 has ranged from 2 to 12 (mean = 4.1) wolves (U.S. Fish and Wildlife Service our files), consistent with historical pack size estimates (Bednarz 1988 (two to eight wolves); Brown 1988 (fewer than six wolves). Pack size in Mexico between 2011 and 2017 has ranged from 2 to 14 Mexican wolves (personal communication Dr. López-González, Universidad Autónoma de Querétaro, April 10, 2017).

Gray wolves reach sexual maturity just before two years of age and have one reproductive cycle per year. Females are capable of producing a litter of pups, usually four to six, each year (Mech 1970). In the wild, Mexican wolf pups are generally born between early April and early May (Adaptive Management and Oversight Committee and Interagency Field Team [AMOC and IFT] 2005) and remain inside the den for three to four weeks. Some pup mortality is expected prior to den emergence. Our data suggest that on average 4.65 pups are born while 3.25 are counted post den emergence (U.S. Fish and Wildlife Service files). Mexican wolves typically live for four to five years in the wild, although we have documented wolves living to 13 years (U.S. Fish and Wildlife Serivce our files); this is consistent with average gray wolf life expectancy documented in other populations (Mech 1988). Annual survival rate of yearling and adult gray wolves is estimated at 0.55 to 0.86 (Fuller et al. 2003: table 6.6). In the MWEPA, survival rate of pups, yearlings, and adults is estimated at 0.50 (inclusive of den bound mortality), 0.67, and 0.81, respectively between 2009 and 2014 (U.S. Fish and Wildlife Service our files).

A wolf pack establishes and defends an area, or territory, within which pack members hunt and find shelter (Mech and Boitani 2003). Daily and seasonal movements of individual wolves and the pack vary in response to the distribution, abundance, and availability of prey, and care of young. 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 (mountainous terrain that included areas of unsuitable lowland habitat) and lower prey densities associated with the arid environment. Between 1998 and 2015, home range size of 138 denning packs in the MWEPA population averaged 197 mi^2 +/- 125mi^2 (SD) (510 km^2 +/- 324 km^2 (Mexican Wolf Annual Reports 1998-2002 & 2004-2015). The average home range size for 30 non-denning packs during the same time period was 343 mi^2 +/- 313 mi^2 (SD) (888km^2 +/- 811 km^2). Average pack home range size for denning packs has remained fairly consistent during the last 10 years. In Mexico, no estimates of denning versus non-denning pack home ranges have been made. However, López González et al. (2017) estimated the area of activity of 20 Mexico wolf individuals, belonging to three packs, from July to December 2016 ranged from: 1) 23.73 to 34.94 km^2 in Pies ligeros pack; 2) 137.5 to 200.9 km^2 for the Mesa de lobos pack; and 3) 4.26 to 837.9 km^2 for the La Escalera pack.

An individual wolf, or rarely a group, will disperse from its natal pack in search of vacant habitat or a mate, typically between nine to 36 months of age. These dispersals may be short trips to a neighboring territory, or a long distance journey of hundreds of miles (Packard 2003). 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). Dispersing wolves tend to have a high risk of mortality (Fuller et al. 2003). In the MWEPA population, dispersal was hindered by a restrictive rule from 1998 through 2014 that required removal of wolves that dispersed outside the boundaries of the Gila and Apache National Forests (63 FR 1752; January 12, 1998; and see "Abundance, Trend, and Distribution of Mexican Wolves in the United States"). Thus a proportion of dispersal events ended in mortality (16.5 %) or ended with the removal of the wolf due to the boundary rule (12%). However, 55% of dispersal events documented between 1998-2015 ended with the wolf successfully locating a mate (U.S. Fish and Wildlife Service). In Mexico, mortality associated with dispersal has not yet been analyzed (personal communication, Dr. López-González, Universidad Autónoma de Querétaro, April 10, 2017).

<u>Ecology and Habitat Characteristics</u>

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 1,219-1,524m (4,500-5,000 ft) (Brown 1988). 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 1988). Wolves traveled between suitable habitats using riparian corridors, and later, roads or trails (Brown 1988).

We recognize that the suitability of an area to sustain wolves is influenced by both biophysical (vegetation cover, water availability and prey abundance) and socioeconomic (human population density, road density and land status) factors (Sneed 2001). Today, we generally consider the most important habitat attributes needed for wolves to persist and succeed in pack formation to be forest cover, high native ungulate density, and low livestock density, while unsuitable habitat is characterized by low forest cover, and high human density and use (74 FR 15123, pp. 15157-15159, Oakleaf et al. 2006; see the Service's 2009 Northern Rocky Mountains distinct populations segment delisting rule for more information on wolf habitat models (74 FR 15123, pp. 15157-15159). Suitable wolf habitat has minimal roads and human development, as human access to areas inhabited by wolves can result in increased wolf mortality (e.g., due to illegal killing, vehicular mortality, or other causes). Public lands such as National Forests are considered to have more appropriate conditions for wolf reintroduction and recovery efforts in the United States than other land ownership types because they typically have minimal human development and habitat degradation (Fritts and Carbyn 1995). Recovery of Mexican wolves in the MWEPA relies on the occupancy of National Forests (USFWS 2014). The reestablishment effort in Mexico is also located in an area of low human density and roads, although not on federal lands. Land tenureship in Mexico differs in that the federal government does not hold large tracts of land; rather, private lands and communal landholdings, such as ejidos, comprise the largest forms of land tenure in Mexico (Valdez et al. 2006) (See Current Conditions).

Description of the MWEPA in the United States

As described by Wahlberg et al. 2016, the MWEPA varies considerably in elevation and topography, ranging from 10,000 feet in the mountains to below 1,000 feet in southwestern Arizona. The dominant physical feature is in the southern-most portion of the Colorado Plateau, known as the Mogollon Rim, which extends from central Arizona to west-central New Mexico. The Mogollon Rim forms the source of the Gila-Salt-Verde River system, which combine in Arizona and flow westward into the Colorado River. The eastern portion of the Mogollon Rim forms the western boundary of the Rio Grande River valley in New Mexico, which has its origin in Colorado, north of the MWEPA, and flows north to south. East of the Rio Grande Valley, mountains also separate the Rio Grande from the Pecos River, which flows south to join the Rio Grande in Texas. In southeastern Arizona/southwestern New Mexico, the isolated mountain ranges separating these river systems are referred to as the "Sky Islands" of the Southwest.

The drainages associated with these river systems contain riparian vegetation dependent on the water table with elevation and disturbance patterns influencing the specific type of vegetation. The amount of riparian vegetation (Table 1), though less than 1% of the total MWEPA, is very important to wolves since it provides water, and in many cases cover, and often serves as a means of easy movement in areas with rapid changes in elevation (Wahlberg et al. 2016).

The elevation variations found within the MWEPA result in considerable variation in vegetation communities. The low elevation areas of southern Arizona and southern New Mexico are desert communities dominated by creosote bush (*Larrea tridentata*) and succulent species (e.g., *Agave* spp., *Opuntia* spp.), intergrading to semi-desert grasslands and shrublands at higher elevation. Much of the area in southeastern New Mexico is part of the southeastern Great Plains. Together, the desert communities and grasslands make up more than 70% of the area of the MWEPA (Table 1) (Wahlberg et al. 2016).

Between 3,000 to 4,000 feet in elevation, transition to woodlands begins. Most woodlands in the MWEPA are dominated by junipers (*Juniperus* spp.), with pinyon (*Pinus* spp.) and oaks (*Quercus* spp.) also present. Woodlands make up more than 16% of the MWEPA (Table 1), and are typically found just below the high-elevation forest communities. These higher elevation forest communities (beginning at approximately 5,000 feet), are characterized by Ponderosa pine (*Pinus ponderosa*) at the lower elevations, with increasing occurrence of Douglas-fir (*Pseudotsuga menziesii*), true firs (*Abies* spp.) and spruce (*Picea* spp.) higher in elevation. While only about 7% of the total area of the MWEPA (Table 1) is composed of these vegetation types, forested communities dominate most of the Mogollon Rim and at higher elevations of the Sky Islands in southeastern Arizona, and southwestern and southeastern New Mexico (Wahlberg et al. 2016).

More than 40% of the MWEPA is administered by Federal agencies, with the Bureau of Land Management and Forest Service administering the most land. The BLM lands are predominately desert and grassland communities (approximately 89% of BLM lands, 17% of the MWEPA), while the Forest Service lands are predominately woodland and forest (approximately 72% of National Forest, 11% of the MWEPA). Approximately 31% of the MWEPA is owned by private individuals; about 19% of these privately owned lands are grasslands, and about 10% are either desert or woodlands. Very little forest land is in private ownership, compared with a substantial amount of riparian areas that are in private ownership (Table 1) (Wahlberg et al. 2016).

State and Tribal lands comprise approximately 25% of the MWEPA. As with private lands, much of these lands are deserts, grasslands, and woodlands, though forests constitute a higher percentage on tribal lands than either state or private lands (Table 1) (Wahlberg et al. 2016).

Table 1. Land ownership and vegetation types (acreage and percentage) within the Mexican Wolf Experimental Population Area (or MWEPA), United States (derived from Wahlberg et al. 2016).[1]

Vegetation	BLM	Forest Service	Other Federal	State	Tribal	Private	Total
Developed/ Non-vegetated	251,100 (0.30%)	122,100 (01.10%)	214,500 (0.20%)	138,800 (0.10%)	54,500 (0.10%)	311,800 (0.30%)	**1,092,900 (0.10%)**
Riparian	59,500 (0.10%)	226,100 (0.20%)	118,600 (0.10%)	59,700 (0.10%)	52,300 (0.00%)	236,700 (0.20%)	**752,900 (0.70%)**
Desert	9,024,400 (9.20%)	855,200 (0.90%)	6,290,000 (6.40%)	4,303,400 (4.50%)	3,386,400 (3.50%)	5,278,500 (5.60%)	**29,137,900 (30.20%)**
Grassland	7,866,100 (8.10%)	2,042,000 (2.10%)	1,369,200 (1.40%)	8,073,900 (8.50%)	2,222,200 (2.30%)	18,326,000 (19.30%)	**39,899,400 (41.70%)**
Shrubland	530,500 (0.40%)	1,101,700 (1.10%)	108,700 (0.10%)	803,100 (0.40%)	484,900 (0.40%)	1,415,700 (0.50%)	**4,444,700 (3.00%)**
Woodland	1,266,400 (1.30%)	6,196,900 (6.30%)	286,800 (0.30%)	1,574,000 (1.60%)	2,158,000 (2.20%)	4,664,700 (4.70%)	**16,146,700 (16.40%)**
Forest	87,000 (0.10%)	4,720,800 (4.80%)	42,900 (0.00%)	98,700 (0.10%)	1,322,000 (1.30%)	493,800 (0.50%)	**6,765,100 (6.90%)**
Total MWEPA Acres	**1,9085,000 (19.40%)**	**15,264,900 (15.50%)**	**8,430,700 (8.60%)**	**15,051,600 (15.30%)**	**9,680,3002 (9.90%)**	**30,727,3004 (31.30%)**	**98,239,800 (100.00%)**

Due to the variety of terrain, vegetation, and human land use within the MWEPA, a matrix of suitable and unsuitable habitat for Mexican wolves exists. We previously estimated that approximately 68,938 km^2 (26,617 mi^2) of suitable habitat exists in the MWEPA (of 397,027 km^2 (153,293 mi^2) (including Zone 3 of the MWEPA; not including tribal lands) (USFWS 2014). More recently, Martínez-Meyer et al. (2017) estimate 44,477 km^2 (17,173 mi^2) of high quality habitat in the MWEPA.

Description of the Sierra Madre Occidental in Mexico

The Sierra Madre Occidental is the longest mountain range in Mexico, extending from near the U.S.-Mexico border to northern Jalisco (González-Elizondo et al. 2013). It has a rugged physiography of highland plateaus and deeply cut canyons, with elevations ranging from 300 to 3,340 m (González-Elizondo et al. 2013). Three primary ecoregions occur in the Sierra Madre Occidental, the Madrean, Madrean Xerophylous and Tropical regions (González-Elizondo et al. 2013). Five major vegetation types occur within the Madrean region, including pine forests, mixed conifer forests, pine-oak forests, oak forests, and temperate mesophytic forests (González-Elizondo et al. 2013). Two major vegetation types occur within the Madrean Xerophylous region, including oak or pine-oak woodland and evergreen juniper scrub (González-Elizondo et al. 2013).

[1] Totals may not add up due to rounding acres to the nearest 100.

In Mexico, López González et al. (2017) found that Mexican wolves use pine oak forest and pine forest according to availability, but avoid other types of vegetation, thus indicating a preference for pine oak and pine forests (Figure 6). According to González-Elizondo et al. (2013) pine-oak forests cover about 30% of the the Sierra Madre Occidental from 1,250 to 3,200 m while pine forests cover 12% of the Sierra Madre Occidental and occur between 1,600 and 3,320 m. Other major vegetation types in the Sierra Madre Oriental include oak forests which cover almost 14% and occur from 340 to 2,900 m, and oak or pine-oak woodlands which cover more than 13% and occur from 1,450 to 2,500 m (González-Elizondo et al. 2013).

Martínez-Meyer et al. (2017, Table 10) estimate two large patches of suitable habitat of 21,538 km^2 (8316 mi^2) and 34,540 km^2 (13339 mi^2) in this area, with a swath of lower quality habitat between them. Three Áreas Naturales Protegidas (or Natural Protected Areas) in Chihuahua (Tutuaca-Papigochi, Campo Verde and Janos), one in Sonora (Ajos-Bavispe) and one in Durango (La Michilía, as well as the proposed protected area Sierra Tarahumara) partially overlap with the largest high-quality Mexican wolf habitat patches in the Sierra Madre Occidental. Between 2011 and 2017, wolves have occasionally been documented in these natural protected areas; use of these areas may increase as the wolf population expands (personal communication, Dr. López-González, Universidad Autónoma de Querétaro, April 10, 2017).

Figure 6. Mexican wolf habitat in Chihuahua, Mexico (credit: Laura Saldivar, Universidad Autónoma de Querétaro/CONANP).

Mexican Wolves and Prey

Wolves are highly-adaptable prey generalists that can efficiently capture a range of ungulate prey species of widely varying size. Studies of gray wolf hunting behavior indicate that wolf hunting strategy is plastic and capable of adjusting for variously sized prey (MacNulty 2007, Smith et al. 2004) by varying the age, size (males vs. females), behavior, and hunting group size within one pack depending on the situation and species of prey (MacNulty et al. 2009, 2012). Wolf density is positively correlated to the amount of ungulate biomass available and the vulnerability of ungulates to predation (Fuller et al. 2003).

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, behavioral,flight, gregariousness, migration) (MacNulty et al. 2007, Creel et al. 2008, Liley and Creel 2008,), and wolves are frequently unsuccessful in their attempts to capture prey (Mech and Peterson 2003, Smith et al. 2004). Generally, wolves tend to kill young, old, or injured prey that may be predisposed to predation (Mech and Peterson 2003, Eberhardt et al. 2007, Smith and Bangs 2009). Wolves have been found to regulate prey populations at lower densities, but only in extreme circumstances have they been documented exterminating a prey population, and then only in a relatively small area (Dekker et al. 1995, Mech and Peterson 2003, White and Garrott 2005, Becker et al. 2009, Hamlin and Cunningham 2009).

Elk, which are common in portions of the MWEPA (USFWS 2014), comprise the bulk of the biomass in the diet of wolves in the MWEPA (Paquet et al. 2001, Reed et al. 2006, Carrera et al. 2008, Merkle et al. 2009a). Although white-tailed and mule deer are present, Mexican wolves' preference for elk may be related to the gregariousness, higher relative abundance, and consistent habitat use by elk. There is also a possibility that the methodologies of diet studies may be biasing data analysis because only large scats were collected and analyzed to minimize the probability of including coyote scat (Reed et al. 2006, Carrera et al. 2008, Merkle et al. 2009a). This may have excluded some adult and all juvenile Mexican wolves from the analysis. However, investigations of ungulate kill sites using locations from GPS-collared wolves support the scat analysis showing most ungulates killed are elk (Arizona Game and Fish Department files). Mexican wolves in the MWEPA have also been found to feed on adult and fawn deer, cattle, small mammals, and occasionally birds (Reed et al. 2006, Merkle et al. 2009a).

In Mexico, Salvídar Burrola (2015) detected the presence of 16 distinct prey species in the scat of reintroduced Mexican wolves. White-tailed deer (*Odocoileus virginianus*) was the most important prey both in terms of frequency of occurrence (37.6) and percentage biomass consumed (30.65). Other prey items included cattle (*Bos taurus*), Eastern cottontail (*Sylvilagus floridanus*), yellow-nosed cotton rat (*Sigmodon ochrognathus*), woodrats (*Neotoma*), skunks (*Mephitis* and *Spilogale*), as well as other rodents and birds. Domestic pigs (*Sus scrofa*), which were provided as supplemental food for wolves, were also an important food item (Salvídar Burrola 2015). Hidalgo-Mihart et al. (2001) found that coyotes in southern latitudes had a greater dietary diversity and consumed smaller prey items than northern latitudes. The small endangered red wolf also has a diet that includes more small items than does the diet of larger northern wolves (Phillips et al. 2003, Dellinger et al. 2011).

Mexican wolves will also prey on livestock in the MWEPA and Sierra Madre Occidental Mountains in Mexico. In the MWEPA, between 1998 and 2015, 288 confirmed cattle depredations were documented, or an average depredation rate of 27 cattle per 100 wolves per year. This depredation rate may represent an underestimate due to incomplete detection of wolf-killed cattle

(Oakleaf et al. 2003, Breck et al. 2011). In Mexico, from 2013 to 2017, 16 confirmed cattle depredations were documented in Chihuahua from Mexican wolves (Garcia Chavez et al. 2017). In both the MWEPA and Mexico, Mexican wolves receive supplemental/diversionary feeding of ungulate carcasses or carnivore logs for various management reasons, such as to allow a pair or pack to adapt to the wild after release (supplementary) or to reduce the likelihood of cattle depredation (diversionary).

Historically, Mexican wolves were believed to have preyed upon white-tailed deer, 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.*), wild turkeys (*Meleagris gallopavo*), and small rodents (Parsons and Nicholopoulos 1995). White-tailed deer and mule deer were believed to be the primary sources of prey (Brown 1988, Bednarz 1988, Bailey 1931, Leopold 1959), but Mexican wolves may have consumed more vegetative material and smaller animals than gray wolves in other areas (Brown 1988) as do coyotes in southern latitudes (Hidalgo-Mihart et al. 2001). The difference between historical versus current prey preference in the United States is likely due to the lack of elk in large portions of historical Mexican wolf range.

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). Although vegetation and climate vary across the range of the Mexican wolf, the region as a whole is generally more arid than other regions of North America with recovered gray wolf populations such as the Northern Rocky Mountains and Western Great Lakes, resulting in lower primary productivity in the range of the Mexican wolf than in these areas (Carroll et al. 2006). The lower productivity of the vegetative community influences productivity up through several trophic levels resulting in lower inherent herbivore resiliency in the Southwest than their northern counterparts (Heffelfinger 2006). Deer species available to Mexican wolves may be smaller in size, have lower population growth rates, exist at lower densities, and exhibit patchy distributions. However, lack of widespread winterkill of ungulates means that lower recruitment is able to sustain a stable population compared to northern ungulate populations. Southwestern deer herds (mule deer and whitetailed deer) require 35-50 fawns per 100 does to remain stable (Heffelfinger 2006), while those in the northern Rocky Mountains require 66 fawns per 100 does for population maintenance (Unsworth et al. 1999).

Predator-prey dynamics may differ in the Southwest compared to other systems as well. Predator populations are sustained more by the productivity of prey populations than by the standing biomass at one point in time (Seip 1995, National Research Council 1997, Carbone and Gittleman 2002). In southwestern deer populations, a compensatory response in deer survival or recruitment would not be expected because deer density is usually kept below the fluctuating carrying capacity through chronically low recruitment (Deyoung et al. 2009, Bower et al. 2014). Computer population simulations of Arizona and New Mexico deer herds showed that an increase in adult doe mortality by only 5-10% was enough to cause population declines because of low and erratic recruitment and no compensatory response (Short 1979). When excluding human harvest, adult female elk survial has been found to be relatively high (Ballard et al. 2000). As such, additional adult mortality sources of adult female elk would tend to be more additive and may contribute to population declines.

Kill rates of individual gray 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 a wild, adult gray wolf have been estimated at 1.4 kg/wolf (3 lbs/wolf) to 3.25 kg/wolf (7 lbs/wolf), or about 13 to 30 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, Peterson and Ciucci 2003).

The Mexican Wolf Interagency Field Team used clusters of wolf GPS locations to estimate kill rates (prey killed/wolf/day) (or kg/wolf/day). The results indicated that during 2015 and 2016 a single Mexican wolf would kill on average the equivalent of 16.45 cow elk, scavenge 1.21 cow elk, and kill 3.93 mule deer does and 0.5 white-tailed dear annually, which equates to 7.19 kg/wolf/day. However, the Interagency Field Team notes that: "The average standardized impacts of Mexican wolves on prey we calculated are likely overestimated because of the four months of hunting season outside of the winter and summer study periods when scavenging likely makes up a significant portion of the diet of Mexican wolves. This estimate is slightly higher than the average, but within the range observed in similar studies conducted on northern gray wolves."

Wolves may also affect 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. Wolves could affect biodiversity and ecosystem processes through two mechanisms: a behaviorally mediated or numeric response on prey – or both (Terborgh et al. 1999). Such trophic cascade 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, Hebblewhite and Smith 2010, Ripple and Beschta 2011, Baril et al. 2011).

Kauffman et al. (2010) used a more rigorous experimental design than previous studies and found no widespread general reduction in browsing on aspen, nor an increase in plant height that would be evidence of a behaviorally mediated trophic cascade. They noted that plant height and browsing are both strongly influenced by many environmental forces unrelated to wolves (Kauffman et al. 2013). Middleton et al. (2013) found no relationship between the risk of an elk being preyed upon by wolves and elk body fat and pregnancy. These finding also failed to support the existence of behaviorally mediated trophic cascades operating in Yellowstone National Park. The dramatic numerical reduction in elk abundance in Yellowstone National Park has relaxed browsing pressure on some plants and resulted in a spatially inconsistent recovery of riparian vegetation, but not to the extent reported widely in the popular media.

Numerous studies conducted in the Northern Range of Yellowstone National Park demonstrate that fire and hydrologic changes strongly influence willow growth and recruitment (Johnston et al. 2007, Bilyeu et al. 2008, Tercek et al. 2010), snow strongly influences elk habitat selection (Mao et al. 2005), use of aspen sites (Brodie et al. 2012), and intensity of browsing versus grazing (Creel and Christianson 2009). Studies in Yellowstone National Park also cast doubt on the cascading effects of wolf recovery on willows (Bilyeu et al. 2007, 2008; Johnston et al. 2007, 2011; Wolf et al. 2007; Creel and Christianson 2009; Tercek et al. 2010). In addition, other ecological changes that can impact vegetation recovery have occurred in Yellowstone National Park concurrent with wolf recovery. Moose abundance has declined markedly following the extensive fires in 1988 (Tyers 2006), grizzly bear abundance has increased dramatically (Schwartz et al. 2006) with a threefold increase in elk calf predation rates (Barber-Meyer et al. 2008), a drought in the mid- to late-1990s, human antlerless elk harvest, and heavy winter snows have impacted elk population abundance (Creel and Christianson 2009). It is now widely understood that assuming the presence of wolves is responsible for all variance in plant growth or recovery in Yellowstone National Park (Beschta and Ripple 2013) is an oversimplification of a complex system.

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, Mexican wolves may interact with coyotes, mountain lions (*Puma concolor*), and black bears (*Ursus americanus*) (AMOC and IFT 2005; USFWS 2010). We do not have data suggesting competition with non-prey species is impacting population dynamics for Mexican wolves in the MWEPA or Mexico.

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). In 2014, we summarized wolf-human interactions in the MWEPA in our EIS, "Final Environment Impact Statement for the Proposed Revision to the Regulations for the Nonessential Experimental Population of the Mexican Wolf" (USFWS 2014). In short, prior to the extirpation of Mexican wolves in Arizona and New Mexico in the 1970s, there are no confirmed or reliable reports of Mexican wolf attacks that occurred on humans, or wolf-caused human fatalities. Subsequent to the 1998 initiation of the reintroduction of Mexican wolves, wolf-human interactions have occurred but there have been no attacks on humans (USFWS 2014). In Mexico, since the reintroduction in 2011, no attacks or aggression toward humans by wolves have been documented (personal communication Dr. López-González, Universidad Autónoma de Querétaro, April 10, 2017).

Humans 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 shooting (including legal shooting to protect livestock, pets, or rarely for human safety). In areas where humans are tolerant to the presence of wolves, wolves demonstrate an ability to persist in the presence of a wide range of human activities (e.g., near cities and congested areas) (Fritts et al. 2003). In the most recent analysis of habitat suitability, Martínez-Meyer et al. 2017 used 1.52 humans/km^2 as a threshold of

Mexican wolf habitat suitability based on Mlandenoff (1995). In the MWEPA, gunshot related mortality is the biggest mortality source for Mexican wolves (USFWS 2017b; 80 FR 2488, January 16, 2015).

SPECIES' CURRENT CONDITION

<u>Abundance, Trend, and Distribution of Mexican Wolves in the United States</u>

The MWEPA population can be characterized as a relatively small but growing population. After exhibiting moderate growth in the initial years of the reintroduction (1998-2003), followed by a period of relative stagnation from 2003-2009, the MWEPA has exhibited sustained population growth for the last seven years (with the exception of 2014-2015) with relatively strong adult survival. The 2016 annual minimum population estimate for the MWEPA was 113 wolves, the largest population size reached by the MWEPA population in its 19 years (U.S. Fish and Wildlife Service files) (Figure 7).

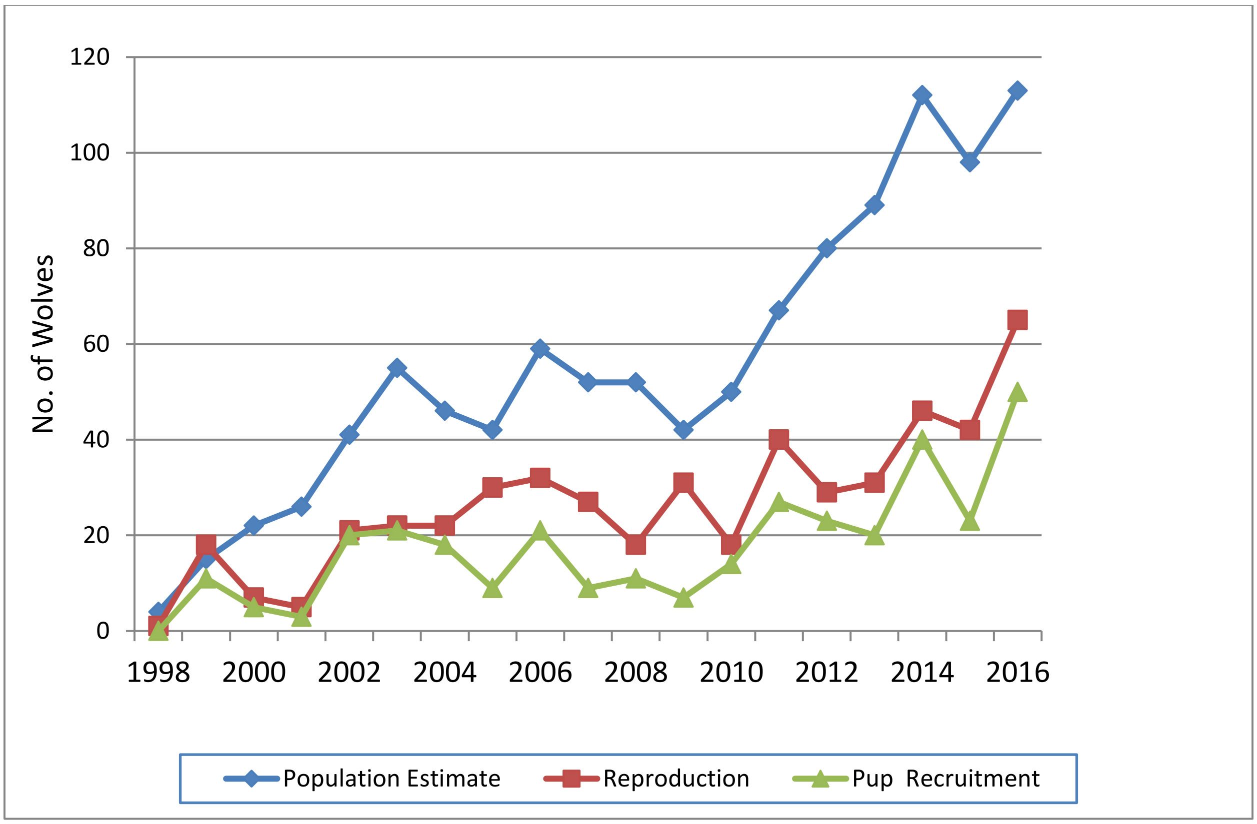

Figure 7. Annual Minimum Population Estimate of Mexican Wolves in the MWEPA, 1998-2016 (U.S. Fish and Wildlife Service files).

The demographic performance of the MWEPA population is influenced by both natural and anthropogenic forces, which is not suprising given the intensity of management of wild wolves. In 2016, all of the wolves in the MWEPA were wild-born, with the exception of surviving cross-fostered pups from captivity (a minimum of one), demonstrating that population growth is driven by natural reproduction rather than the release of wolves from captivity; only 10 initial releases, including 6 cross-fostered pups from captivity, were conducted between 2009-2016. 2016 marked the 15th consecutive year in which wild born wolves bred and raised pups in the wild. Our data suggest that probability of an adult pair producing pups in the wild is a function of age of the dam and relationship of the paired female to her mate (i.e., the predicted inbreeding coefficient of the pups). Average litter size in the MWEPA has been estimated at 4-5 pups between 1998-2016 (U.S. Fish and Wildlife Service files). However, our monitoring data suggest that the maximum number of pups in the summer is affected by feeding efforts. Packs that have received diversionary feed (road-killed native prey carcasses or carnivore logs) are larger than those that have not, likely due to improved summer survival of pups due to reduced pup mortality from malnutirition and reduced susceptibility or mortality as a result of disease (See Miller 2017, “Calculation of litter size”).

Survival, or conversely mortality, of Mexican wolves in the MWEPA is substantially affected by anthropogenic forces. The average Mexican wolf in the MWEPA is 3.37 years old and has been monitored for 2 years at the time of its mortality or removal from the wild, with estimated survival rates of 0.5 for pups (0-1 year old, inclusive of estimated mortality based on observations), 0.67 for subadults (1-2 years old), and 0.81 for adults (greater than 2 years old) from 2009 to 2014 (U.S. Fish and Wildlife Service files). Causes of Mexican wolf mortality in the MWEPA have been largely human-related, including vehicle collision, and gunshot and trapping related incidents. Natural causes such as dehydration, disease, intraspecific and interspecific attack account for less than 17% of documented mortality, and unknown causes have been documented but account for 11% of known mortality. The combination of human caused mortality from shooting and trapping incidents (77 of 133 documented mortalities [only four of these were trapping incidents], or 58% of total documented mortalities) and human caused mortality from vehicular collision (16 of 133 documented mortalities, or 12% of total mortalities) accounts for 70% of documented wolf mortalities from 1998 to 2016 (USFWS 2017b).

Our removal of Mexican wolves from the MWEPA for management reasons is also functionally the same as mortality to the population. The majority of wolf removals are the result of conflicts or interactions with humans, including those associated with livestock. Wolf removals are conducted in response to livestock depredation (76, including 13 lethal removals), boundary violations (49; conducted under the previous 1998 10j rule), nuisance behavior (24), and other reasons (28) (USFWS 2017b). In some years, the overall “failure rate” (wolf mortality + removals plus missing wolves) of the population has resulted in decreasing or stagnant population trends, such as the period from 2004-2009 (AGFD 2007; USFWS 2004, 2005, 2006, 2008, 2009).

Over the course of the reintroduction, our management of the MWEPA population has impacted its performance. We consider the MWEPA population to have gone through three stages of management: the period from 1998 through 2003, which was characterized by a high number of initial releases and translocations and a moderate number of removals; the period from 2004 through 2009, during which we conducted a moderate number of initial releases and translocations and a high number of removals; and the period from 2010 through 2016, which was characterized by a low number of releases and translocations but also a low number of removals (Miller 2017, Figure 1).

Our shift in management response to depredating wolves was the driving factor behind the transition from the second to the third management stage. For several years (in particular 2005-2007) we conducted a significant number of depredation-related removals to address social and economic concerns from local ranching communities. After observation of the negative impact the high number of removals was having on population performance, we lessened our removal rate by focusing on working with landowners and permittees to implement proactive management techniques such as range riders, fladry, and non-lethal ammunitions to minimize the likelihood of depredations. One of our proactive techniques is a program of diversionary feeding. Diversionary food caches are road-killed native prey carcasses or carnivore logs provided to denning wolves to reduce potential conflicts with livestock in the area. Diversionary food caches have been used on increasing proportions of the population since 2009, providing about 10 pounds of meat per wolf every two to three days sometimes for several months when the likelihood of depredations are high (e.g., during denning season). In 2016, we provided diversionary feeding for approximately 70% of the breeding pairs during denning season (U.S. Fish and Wildlife Service files). This management change away from wolf removal and toward proactive management, coupled with a shift toward mostly wild-born wolves was accompanied by a lower mortality rate in the population.

The distribution of wolves in the MWEPA is also influenced by both natural and anthropogenic forces, namely habitat availability and quality, and our management of dispersing wolves. Mexican wolves occupied 13,329 mi^2 (34,522 km^2) of the MWEPA during 2015 (USFWS 2015). We expect that over the next few years the distribution of the population will continue to expand naturally within the MWEPA as the size of the population increases. As previously described, Mexican wolves are capable of dispersing long distances. Our management regime curtailed the natural movement patterns of Mexican wolves in the MWEPA due to the geographic regulatory restrictions from 1998 to 2014 requiring capture of wolves that dispersed outside of the Gila and Apache National Forests (63 FR 1752; January 12, 1998) and Fort Apache Indian Reservation: 12% of dispersal events resulted in mortality due to the boundary rule (U.S. Fish and Wildlife Service files). Similarly, wolves are now not allowed to disperse beyond the revised MWEPA boundaries we established in 2015 (80 FR 2512-2567, January 16, 2015). We expect that the revised boundaries, although considerably more expansive than the boundaries originally established in 1998, may still limit some dispersal movements. (The revised regulations expand the total area Mexican wolves can occupy from 7,212 mi^2 -- the size of the Gila and Apache National Forests in the 1998 regulations -- to 153,293 mi^2 -- Zones 1, 2, and 3 in the new regulations). Our dispersal data for the MWEPA is, and may continue to be, limited in its ability to inform our complete understanding of the frequency, duration, or distance of longer dispersal events that would typically occur and related changes in distribution.

<u>Abundance, Trend, and Distribution of Mexican Wolves in Mexico</u>

The Mexican wolves that occupy northern Sierra Madre Occidental Mountains can be characterized as an extremely small, establishing population. 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, with the release of five captive-bred Mexican wolves into the San Luis Mountains in Sonora just south of the US-Mexico border (SEMARNAT e-press release, 2011). Since that time, from 2012 to 2016, 41 Mexican wolves have been released into the state of Chihuahua, 18 of which died within a year after release (Garcia Chavez et al. 2017). Out of 14 adults released from 2011 to 2014, 11 died or were believed dead, and 1 was removed for veterinary care. Of these 11 Mexican wolves that died or were believed dead, 6 were due to illegal killings (4 from poisoning and 2 were shot), 1 wolf was presumably killed by a mountain lion, 3 causes of mortality are unknown (presumed illegal killings because collars were found, but not the carcasses), and 1 disappeared (neither collar nor carcass has been found) (80 FR 2491, January 16, 2015). One pair released in 2013 in Chihuahua has produced three litters (Garcia Chavez et al.

2017). This pair first reproduced in 2014, with 5 pups documented, marking the first successful reproductive event in Mexico since reintroductions were initiated in 2011 (80 FR 2491, January 16, 2015). As of April 2017, approximately 28 wolves inhabit the northern portion of the Sierra Madre Occidental Mountains in the state of Chihuahua (Garcia Chavez et al. 2017).

Genetic Status of the Mexican Wolf

In Captivity

The Mexican wolf captive population is an intensively managed but genetically depauparate population. The small number of founders of the captive population and the resultant low gene diversity available with which to build a captive population have been a concern since the beginning of the project (Hedricks et al. 1997) and remain a concern today (Siminski and Spevak 2016).

As of 2016, the captive population has retained approximately 83% of the gene diversity of the founders, which is lower than the recommended retention of 90% for most captive breeding programs. In its current condition, the population would be expected to retain 75% gene diversity over 60 years and only 70.22% in 100 years. Long-term viability or adaptive potential depends on the store of genetic variability. It is desirable to retain as much genetic variability as possible, but uncertain when there might be potentially damaging loss (Soulé et al 1986). Damaging loss might manifest in compromised reproductive function or physical and physiological abnormality. Reducing the rate of loss could be achieved by increasing the annual population growth rate, increasing the representation of under-represented founders, and by using the genome bank (Siminski and Spevak 2016).

The SSP actively supports both the MWEPA and northern Sierra Madre Occidental reintroductions. Today, relatively few initial releases are conducted into the MWEPA compared with the early years of the program (i.e., 74 captive wolves released in the first five years) because the population is established and population growth occurs via natural reproduction rather than augmentation through releases from captivity (USFWS 2017b). Initial releases are conducted into the MWEPA mostly for genetic management or other specific management purposes, and we expect this pattern to continue. Mexico, currently in the early phase of reintroduction, will likely continue to release a significant number of captive wolves to grow its population for the next few years (i.e., 41 wolves released in the first five years, including both initial releases and translocated wolves from the MWEPA). Releases in Mexico can simultaneously achieve genetic management objectives. For both wild populations, it is desirable to establish adequate gene diversity while the population is small, and then allow the population to grow.

The major challenges facing the SSP include: the limited number of founders; insufficient captive space; and the current demographic instability of the population. The number and relationship of animals founding the SSP population limit the amount of genetic diversity available to the SSP program. As a result, the SSP manages breeding to minimize the rate of loss of the genetic diversity over generations. This includes planned annual parings with priority to those wolves with the least genetic representation in the population. It also means artificially lengthening generation time and thus slowing the rate of loss over time by cryopreserving sperm and eggs beyond the natural life of the individual wolf for use in artificial pairings in the far future. The development and application of assisted reproductive technologies like artificial insemination and *in vitro* fertilization are a priority for the SSP. The SSP established the genome bank in 1990 by collecting and preserving eggs and sperm from Mexican wolves. Techniques to use the material in the genome bank such as artificial insemination are still under development but have been used successfully in a limited number of instances (Siminski and Spevak 2016).

The SSP seeks to increase the number of holding facilities in recognition that a larger population will retain genetic diversity longer than a small population. In order to promote demographic stability, the SSP needs to breed a greater proportions of its population each year. This requires increased space and greater efficiency in managing the SSP population. Improvements in SSP wolf husbandry through regular revisions of its husbandry manual are another priority for the SSP.

The captive population is currently demographically unstable because the age pyramid of the population is top heavy with older animals (that is, the population consists of many more older animals than young). The SSP population grew slowly from its founding in the late 1970s through the 80s, and then grew exponentially through the 90s hitting a peak population in 2008 of 335 wolves. In response to the cut back in releases to the wild and having reached maximum capacity in about 47 holding facilities, the SSP deliberately reduced its reproduction to stabilize the SSP population below 300 wolves within a stable age pyramid in the mid-2000's. Maintaining a stable age pyramid between 280 and 300 has proven difficult however, and the SSP estimates it may take another five years to achieve a stable age pyramid at a population size below 300.

In the Wild

The genetic status of Mexican wolves in the wild is as much or more of a concern as that of the captive population, namely due to inappropriately high mean kinship (or, relatedness of individuals to one another) in the MWEPA, as well as ongoing loss of gene diversity and concerns over the potential for inbreeding depression to have negative demographic impacts on either the MWEPA or Mexico populations in the future. Unlike the captive breeding program, where specific wolves can be paired to maximize the retention of gene diversity, we cannot control which wolves breed in the wild. Because only over-represented wolves in captivity are potential candidates for release and because of our inability to control breeding in the wild, we expect gene diversity in the wild to be lower than in the captive population. As of 2016, the MWEPA population has a retained gene diversity of 75.91%, while the wolves in Mexico have a retained gene diversity of 66.26%. The representation of the three lineages in the MWEPA are 76.97% McBride, 7.21% Aragon, and 15.83 Ghost Ranch, and 60.94% McBride, 19.79% Aragon and 19.27% Ghost Ranch in Mexico.

As of 2016, Mexican wolves in the MWEPA population were on average as related to one another as siblings (Siminski and Spevak 2016). High relatedness is concerning because of the risk of inbreeding depression (the reduction in fitness associated with inbreeding). Inbreeding depression may affect traits that reduce population viability, such as reproduction (Fredrickson et al. 2007), survival (Allendorf and Ryman 2002), or disease resistance (Hedrick et al. 2003) (and see USFWS 2010 and 80 FR 2504-2506).

Recent exploration of inbreeding depression has been conducted in the captive and MWEPA populations. Fredrickson et al. (2007) analyzed 39 litters (1998-2006) from the MWEPA and reported a negative association between pup inbreeding coefficient (f) and "litter size" (maximum number of pups counted during the summer). However, a more recent analysis of 89 wild litters from 1998 to 2014 found no significant relationship using all available data (Clement and Cline 2016 in Miller 2017, Appendix C). Clement and Cline (ibid) found estimated effect of inbreeding differed during different time periods. The effect of pup f on maximum pup count was negative in the early period (1998-2006), not significant for the entire time period (1998-2014), and positive but not significant for the late time period (2009-2014). They went on to state, "Given the lack of experimental control, it is difficult to understand the cause of the changing relationship through time. However, it could be due to a shift in the population from captive-born animals to wild-born animals, changes in population density, changes in the survey protocol for wild animals, or some unmeasured individual effect".

We are able to positively influence the genetic condition of the MWEPA and northern Sierra Madre Occidental population through the release of genetically advantageous Mexican wolves to the wild from captivity, cross-fostering genetically-valuable pups, translocating wolves between wild popualtions, or potentially by removing Mexican wolves whose genes are over-represented. Management recommendations suggest that the Aragon and Ghost Ranch lineages should be increased to as much as 25% each in the MWEPA (Hedrick et al. 1997) because wolves from these lineages are currently under-represented (Siminski and Spevak 2016).

We have been striving to decrease mean kinship and increase the retention of gene diversity in the MWEPA through the release of wolves from the captive breeding program. In 2014, the Service and our interagency partners began utilizing a technique referred to as cross-fostering. Instead of releasing adult wolves from captivity into the wild, which have a lower survival rate than wild born wolves and a higher incidence of nuisance behavior (AMOC and IFT 2005), we have placed genetically advantageous pups from captive litters into wild dens to be raised with the wild litter. In our first cross-fostering event in 2014, we placed two pups from one wild litter into another wild litter. In 2016, we placed six pups from captivity into three wild litters (two pups into each litter). The success of cross-fostering efforts is measured by pups surviving and breeding, such that their genetic material is integrated into the wild population. To date, we are aware of one instance in which a cross-fostered pup has survived and bred (U.S. Fish and Wildlife Service our files). We will continue to monitor the success of cross-fostering efforts.

Several other genetic issues, including hybridization (between Mexican wolves and dogs or coyotes) and introgression of gray wolves with Mexican wolves are of potential concern to our management of wild Mexican wolves. In the MWEPA population, three hybridization events between Mexican wolves and dogs have been documented since wolves were first reintroduced in 1998. In each case, hybrid litters were humanely euthanized with the exception of one pup of unknown status (80 FR 2504, January 15, 2016). No hybridization events between Mexican wolves and coyotes have been documented. No hybridization events with coyotes or dogs have been documented in Mexico (personal communication Dr. López-González, Universidad Autónoma de Querétaro, April 10, 2017). We recognize that hybridization events could occur and therefore have management protocols in place to respond swifty if hybridization is detected; however, hybridization is not a significant genetic or management concern to Mexican wolves at the level at which it has occurred to date.

We recognize the potential for introgression of gray wolves into Mexican wolf range. Several long-distance dispersal events from other gray wolf populations in recent years suggest that gray wolves could disperse into the MWEPA, where they could breed with Mexican wolves. While the introduction of gray wolf genes into the MWEPA population could result in genetic rescue of the population (Hedrick and Fredrickson 2010, Whiteley et al. 2015), multiple introgression events could quickly swamp the Mexican wolf genome by introducing alleles that might change the natural history or behavior of the population (e.g., Fitspatrick et al. 2010). Careful evaluation of the potential effects of introgression of gray wolves is needed to determine whether allowing gray wolves to breed with Mexican wolves could be appropriate during a later stage of recovery or after recovery (Hedrick and Fredrickson 2010). Until such evaluation occurs and pending its results, we would manage against such breeding events occurring in the MWEPA.

<u>Stressors</u>

The most important biological stressors, or conditions, that may influence the current and ongoing recovery potential of the Mexican wolf include: 1) adequate habitat availability and suitability; 2) excessive human-caused mortality; 3) demographic stochasticity associated with small population size; and 4) continuing or accelerated loss of genetic diversity in the captive or wild populations. In addition to their individual impacts, these stressors can have synergistic effects. For example, high mortality rates may result in declining populations that become less demographically stable and lose gene diversity more rapidly than a more stable, growing population.

Habitat availability/suitability

Wolf reintroduction and recovery efforts require large areas. As previously discussed, suitable habitat for the Mexican wolf is forested, montane terrain containing adequate biomass of wild prey (elk, white-tailed deer, mule deer, and other smaller prey) to support a wolf population. Suitable habitat has minimal roads and human development, as human access to areas inhabited by wolves can result in wolf mortality by facilitating illegal killing. A recent habitat assessment conducted by Martínez-Meyer et al. (2017) assessed information on abiotic climatic variables, land cover and vegetation types, ungulate biomass, human population density, and road density to determine the extent of suitable habitat in the southwestern United States and Mexico. Their study identifies the MWEPA and two areas in the Sierra Madre Occidental of Mexico as the most suitable areas within historical range (per Parsons 1996) to establish Mexican wolf populations to contribute to recovery. These areas have been identified in previous habitat assessments (summarized in USFWS 2010) and two of the three areas (the MWEPA and the northern Sierra Madre Occidental site in Mexico) are the current locations of Mexican wolf reintroductions.

As Martínez-Meyer et al. (2017) recognize, ground-truthing is needed to verify the results of their niche modeling exercise to ensure the areas identified as suitable habitat adequately contain the biological characteristics necessary to support Mexican wolves. Specifically, verifying the availability of ungulate biomass in Mexico is of particular importance, as wolf density is positively correlated to the amount of ungulate biomass available and the vulnerability of ungulates to predation (Fuller et al. 2003). Adequate ungulate monitoring data is available for the MWEPA to inform our understanding of the size of Mexican wolf populations that could be supported. We previously estimated that a population of 300-325 Mexican wolves could be supported in the MWEPA without unacceptable impacts to ungulates (USFWS 2014). However, in Mexico ungulate monitoring methodologies are more variable and data is not readily available in the area of interest, making predictions about ungulate biomass as a characteristic of habitat suitablity considerably less certain (Martínez-Meyer et al. 2017). We recognize that ungulate availability is lower in the Sierra Madre Occidental sites compared with the MWEPA, in large part due to the absence of elk in Mexico, as well as lower deer densities (Martínez-Meyer et al. 2017). Lower density of ungulates in Mexico would suggest that wolves in Mexico will likely have smaller pack sizes and larger home ranges relative to wolves in the MWEPA (Fuller et al. 2003). Historically Mexican wolves subsisted in this area, likely with a larger proportion of small mammals in their diet compared to wolves in other areas (Brown 1988). As Mexico continues efforts to establish a population of Mexican wolves in the Sierra Madre Occidental, information about ungulate (or other prey) abundance and density will be informative to more fully understand the area's ability to support wolves.

In addition to ecological differences between the United States and Mexico reintroduction sites, we also recognize that land tenure in areas of suitable habitat in each country are significantly different. Land tenure differences may result in different opportunities and challenges in each country to establish and maintain Mexican wolf populations. In the United States, we consider federal land to be an important characteristic of the quality of the reintroduction area. Federal lands such as National Forests are considered to have the most appropriate conditions for Mexican wolf reintroduction and recovery efforts because they typically have significantly less human development and habitat degradation than other land-ownership types (Fritts and Carbyn 1995). The majority of suitable habitat for Mexican wolves in the MWEPA occurs on the Apache, Sitgreaves, Coconino and portions of the Tonto, Prescott, and Coronado National Forests in Arizona, as well as on the Fort Apache Indian Reservation and San Carlos Apache tribal lands. In New Mexico, the Gila and portions of the Cibola and Lincoln National Forests are important large blocks of public land (USFWS 2014).

In Mexico, there are three primary types of land: federal, private, and communal (Valdez et al. 2006). Large tracts of federally owned lands managed solely for conservation do not exist in Mexico. Ejidos are a type of communal property distributed among individuals but owned by the community that may have conservation objectives but are typically managed for multiple uses including extraction of natural resources such as timber or mining (Valdez et al. 2006). Natural Protected Areas are managed by the federal government in Mexico for the protection, restoration, and sustainable use of the natural resources, but many have native or rural communities living within their boundaries, and are a mix of private, federal, and communal land. Most Natural Protected Areas do not have comprehensive management plans, and extractive uses are allowed (Valdez et al. 2006). Because the Mexican landscape is dominated by privately and communally owned lands, landowner approval is necessary before Mexican wolves can be released onto private land. As in the United States, landowner support for the reintroduction of Mexican wolves ranges from supportive to antagonistic (López González and Lara Díaz 2016). Federal agencies in Mexico continue to work with landowners to seek support for the reintroduction of Mexican wolves and have obtained signed agreements from several cooperative landowners who have allowed for the reintroductions to date.

Successful Mexican wolf recovery will require that Mexican wolf populations occupy large areas of ecologically suitable habitat. Prey availability will need to be adequate to support populations, and land tenure and management, although potentially different between the two countries, will need to support the occupancy and management of Mexican wolves across the landscape.

Mortality

Results from research on gray wolves (Fuller et al. 2003, Carroll et al. 2006), our monitoring data, and the Vortex population modeling analysis (Miller 2017) suggest that Mexican wolf populations are highly sensitive to adult mortality. For populations to grow or maintain themselves at demographic recovery targets, mortality rates will need to stay below threshold levels (Miller 2017).

As previously described, human-caused mortality is the most significant source of documented mortality in the MWEPA (USFWS 2017b; 80 FR 2488, January 16, 2015), and therefore the most important single source of mortality to address during the recovery process. The impact of human-caused mortality has varied from a small impact in a given year to reducing the population by about 20% (U.S. Fish and Wildlife Service files). Human-caused mortality may occur at levels significant enough to cause a population decline, or at lower levels may hinder how quickly the population grows (that is, the population is still able to grow, but at a slower rate than it otherwise would). Ongoing and increased law enforcement presence and education to reduce misinformation will continue to be necessary in the MWEPA for the full extent of the recovery effort.

We have also observed that wolves experience a greatly increased likelihood of mortality in their first year after initial release or translocation. Survival of released or translocated wolves is markedly lower than average survival rates for wild wolves (See Miller 2017, Table 3). Functionally this means that a greater number of wolves need to be released to the wild than the number expected to survive and contribute to the population (e.g., we release 10 wolves in order to get 2 wolves that survive as potentially reproductive members of the population).

As we have observed in the MWEPA, the combination of mortality and management removals (which serve as mortality to a population) can have a significant impact on population performance. While some level of removal is a useful management tool to address conflicts with livestocks or humans, excessive removals can be counterproductive to population performance, particularly during years when the population is experiencing higher mortality rates or slower growth. Livestock depredations and conflicts with humans are the major causes of management removals that are likely to continue in the future, and therefore the most important source of removal to consider as it relates to the recovery of the Mexican wolf. Many considerations are taken into account when determining whether to remove wolves, including the status of the population and the genetics of individual wolves. During years in which a population exhibits robust growth (low mortality rates), higher levels of removal could occur without hindering the population (Miller 2017). During years with higher mortality rates, removal rates would need to be lessened or eliminated to support population stability. Maintaining and expanding the use of proactive techniques to deter depredation events will continue to be necessary throughout the recovery effort, and possibly indefinitely.

In summary, populations that contribute to recovery will need to experience alleviated levels of human-caused mortality that do not hinder population growth. Furthermore, while we recognize that management removals will remain a useful management tool during the recovery process, we envision that the populations that contribute to recovery will be managed with a suite of tools to reduce conflicts, of which removal will be only one. To track the impact of mortality and removals, ongoing monitoring and data collection will need to continue in both the MWEPA and Mexico, with frequent adjustments in management to respond to the status and performance of populations. Improving the survival of released and translocated wolves could greatly improve our progress toward demographic or genetic recovery goals.

Demographic stochasticity

As we explained in the final listing rule for the Mexican wolf, Mexican wolves in the wild have a high demographic risk of extinction due to small population size. Scientific theory and practice generally agree that a subspecies represented by a small population faces a higher risk of extinction than one that is widely and abundantly distributed (Goodman 1987, Pimm et al. 1988). One of the primary causes of this susceptibility to extinction is the sensitivity of small populations to random demographic events (Shaffer 1987, Caughley 1994). In small populations, even those that are growing, random changes in average birth or survival rates could cause a population decline that would result in extinction. This phenomenon is referred to as demographic stochasticity. As a population grows larger and individual events tend to average out, the population becomes less susceptible to extinction from demographic stochasticity and is more likely to persist.

At their current sizes, both the MWEPA and northern Sierra Madre Occidental populations have a high risk of extinction that must be ameliorated during the recovery process. Miller 2017, suggests that if both populations were maintained at or near their current population size for 100 years, the MWEPA would have approximately a 45% risk of extinction, and then northern Sierra Madre Occidental wolves would have a 99% risk of extinction (see Conclusions and Discussion: Analysis of the Status Quo).

We envision populations that contribute to recovery to exhibit moderately low levels of demographic stochasticity, meaning that they demonstrate population dynamics (as growing or stable populations) that suggest they are unlikely to go extinct now or in the foreseeable future (50-100 year time horizon). Neither the ESA nor the Service equate a specific extinction risk with the definitions of "endangered" or "threatened", but rather the Service recognizes this is a species specific determination that should be explored during the development of conservation measures and recovery plans for listed species. Therefore, population growth will be necessary for both populations to reduce the risk of stochastic population fluctuations that could threaten their ability to persist over time (see additional discussion in subsection "Resiliency").

Loss of gentic diversity

As described above, both the captive and wild Mexican wolf populations lose gene diversity every year as animals die or reach reproductive senesence. Because there are no new founders to bring new genes to the population, we focus our efforts on slowing the rate of loss of diversity. This is more easily accomplished in captivity than the wild due to our ability to manage pairings.

Inbreeding depression is not currently operating at a level that is suppressing demographic performance in the MWEPA (in fact, the population has exhibited robust growth in recent years), yet we remain aware that the population has high levels of mean kinship and does not likely contain an adequate amount of the gene diversity available to it from the captive population. (We are unable to make statements about the demographic performance of the northern Sierra Madre Occidental wolves due to the short time frame of the reintroduction effort and specifically a lack of data on reproduction). The recent growth of the MWEPA in its current genetic condition compounds the situation, because it becomes harder to improve gene diversity as the population grows larger. In other words, more releases of wolves would be necessary to shift the genetic composition of the population than at a smaller population size. Miller 2017 demonstrates that without active genetic management in the form of releases and translocations (which could also include cross-fostering) in either reintroduction area, genetic drift leads to reduced genetic variability over time (see Scenario Set 1). When active genetic management is conducted, populations in the Vortex model are able to maintain a more robust genetic condition that minimizes the likelihood of genetic issues and may provide for longer term adaptive potential (Miller 2017, Scenario Set 2).

We envision populations that contribute to recovery will be sufficiently genetically robust as to not demonstrate demographic-level impacts from inbreeding depression or other observable, detrimental impacts. We expect that active genetic management will be necessary during the recovery process through a combination of intial releases, translocations, cross-fostering events, or removals, as a precautionary measure to avoid the negative impacts that would be more likely to occur at higher levels of inbreeding depression, such as reduced likelihood of litter production, smaller litter sizes, or other reproductive effects.

RESILIENCY, REDUNDANCY, AND REPRESENTATION

The Service has recently begun using the concepts of resiliency, redundancy, and representation to identify the conditions needed for species recovery. We previously assessed the resiliency, redundancy, and representation of Mexican wolves in the MWEPA in our 2010 Conservation Assessment (USFWS 2010). Since that time, the MWEPA population has grown in abundance and distribution, and Mexico has intiated the establishment of a population in Mexico. We incorporate this new information in our updated discussion of the "3 R's". In combination with our identification of stressors, assessing the resiliency, redundancy, and representation of the MWEPA and northern Sierra Madre Occidental populations will guide our development of an effective recovery strategy in our revised recovery plan for the Mexican wolf that will result in robust populations across its range.

The Service describes resiliency, redundancy, and representation as follows (USFWS 2016):

Resiliency describes the ability of the populations to withstand stochastic events. Measured by the size and growth rate of each population, resiliency gauges the probability that the populations comprising a species are able to withstand or bounce back from environmental or demographic stochastic events.

Redundancy describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can bounce back from catastrophic events.

Representation describes the ability of a species to adapt to changing environmental conditions. Measured by the breadth of genetic or environmental diversity within and among populations, representation gauges the probability that a species is capable of adapting to environmental changes.

Lengthier descriptions of these concepts and their applicability to Mexican wolf conservation and recovery are provided in the 2010 Conservation Assessment (USFWS 2010).

<u>Resiliency</u>

We used population viability analysis to explore the conditions for viability, or resiliency, of wild Mexican wolf populations in the United States and Mexico (Miller 2017). We consider a resilient population to be one that is able to maintain approximately a 90% or greater likelihood of persistence over a 100 year period. Given that the Service does not equate specific levels of viability with endangered or threatened status, we use 90% persistence as a general guideline indicating that populations are highly demographically stable, rather than as an absolute threshold. This benchmark is well supported by the community of practice in recovery planning (Doak et al. 2015) and is appropriate because we have a high degree of certainty of the status of populations based on monthly and annual monitoring, we recognize that wolf populations are able to grow and rebound from population fluctuations rapidly (Fuller et al. 2003), and we want to strike a balance between achieving a reasonable level of viability while also considering the needs of local communities and the economic impact of wolves on some local businesses. In addition to the natural variability in demographic rates used as input for the analysis, an element of extreme stochasticity was incorporated in the model in all scenarios to ensure populations are able to withstand single year reductions in population growth or reproductive rate (See "Catastrophic Event") as may occur during disease events or other unexpected "catastrophes."

Miller's (2017; Scenario Set 1) results suggest that resiliency (~90% persistence over 100 years) of wild Mexican wolf populations can be achieved by various combinations of population size and mortality rate, with larger population sizes needed to accommodate higher mortality rates. The MWEPA population is able to achieve the 90% guideline when managed for a long term abundance of around 300 wolves when adult mortality is below 25%. Given predicted annual variation in abundance, managing for a population of around 300 wolves means that in some years the population will grow larger than 300. At higher mortality rates, larger population sizes are needed to achieve and maintain resiliency. In the northern Sierra Madre Occidental, a population of less than 200 wolves is unable to reach the 90% benchmark except at the lowest tested mortality rate (approximately 19%), which is well below the population's current average adult mortality rate and expected to be unlikely to be achieved during the early years of the reintroduction. Larger population sizes at or above 200-250 are needed for persistence of this population at a mortality rate of approximately 25%, while populations of 200-250 are not able to achieve persistence at mortality rates of 28% and 31%.

<u>Redundancy</u>

The scientific literature does not recommend a specific number or range of populations appropriate for conservation efforts, although rule of thumb guidelines for the reintroduction of a species from captivity recommends that at least two populations be established that are demographically and environmentally independent (Allendorf and Luikart 2007). Recent habitat analysis (Martínez-Meyer et al. 2017) supports previous findings (see USFWS 2010) that there are limited areas within the core historical range of the Mexican wolf with the ecological conditions and size necessary to support Mexican wolf populations: the MWEPA in the United States, and two locations in the Sierra Madre Occidental Mountains of Mexico. Previous studies (Carroll et al. 2004; Carroll et al. 2006) identifed potential areas north of the MWPEA with suitable habitat for Mexican wolf reintroduction, but we are currently focused on historical range identified in Parsons (1996) in collaboration with ongoing recovery efforts in Mexico.

The Mexican wolf is currently distributed in the MWEPA and northern Sierra Madre Occidental in different phases of establishment, as discussed in Current Conditions. The initiation of the reintroduction effort in northern Mexico demonstrates progress in establishing *redundancy* since the 2010 Conservation Assessment (USFWS 2010), but it does not yet fully satisfy this objective. To achieve *redundancy*, populations in these two geographic areas, at minimum, will need to demonstrate sufficient *resiliency* (as described above) such that they provide a true measure of security against extinction for one another. If the southern Sierra Madre Occidental area were used as a reintroduction site and managed appropriately to establish *resiliency* and *representation* (see below), this area could provide an additional level of *redundancy*. Therefore, at minimum we expect *redundancy* can be satisfied by the maintainence of two *resilient*, *representative* populations in the MWEPA and northern Sierra Madre Occidental, with the southern Sierra Madre Occidental potentially providing support to the northern Sierra Madre Occidental site or independently functioning as another opportunity for *redundancy*. The relationship between redundant populations (whether they are connected by natural or assisted migration) is described below in Representation.

Representation

We consider *representation* to have both genetic and ecological aspects that are important to recovery of the Mexican wolf. The population viability analysis of Miller (2017) enabled us to quantify and predict the maintainence of gene diversity in wild and captive populations over time, while the habitat assessment conducted by Martínez-Meyer et al. 2017 enabled our understanding of the ecological conditions across the range of the Mexican wolf, together providing a detailed assessment of *representation*.

We consider the degree to which wild populations contain the gene diversity available from the captive population to be an important indication of genetic *representation* for recovery. As Miller (2017. pg.17) states, "As the SSP population represents the origin of all wolves following the taxon's extirpation to the wild, it is the source of all genetic variation that can be transferred to wild populations." Ensuring wild populations represent approximately 90% of the gene diversity retained by the captive population provides a guideline for *representation* based on community of practice in the management of captive populations (Siminiski and Spevak 2016). We consider approximately 90% to be a reasonable bar for recovery because it ensures wild populations contain a high degree of the genetic diversity available, while recognizing that we cannot control breeding events in the wild and need flexibility in our management of wolves (e.g., removals may impact the gene diversity the population).

Using the pedigree maintained by the SSP for the captive and wild populations, Miller tracked gene diversity (expected levels of heterozygosity) of Mexican wolf populations across several scenario sets of initial release and translocation combinations that could be conducted to improve the genetic condition of wild populations (Miller 2017, Table 2). Miller's results suggest that the number of initial releases from the SSP to the MWEPA that we recommended in our 2014 EIS to improve the genetic condition of the MWEPA (USFWS 2014) would be insufficient for attaining the 90% guideline we consider for recovery. We note that these results were predicted based on assumed survival of only 0.284 of adult wolves (Miller 2017, Table 3). Model results suggest that this guideline could be reached by increasing the number of releases, increasing survival of released animals, or a combination. We recognize there may be many additional release and translocation combinations (including cross-fostering and selective removals) beyond those explored by Miller (2017) by which MWEPA or Sierra Madre Occidental populations could reach the 90% guideline.

Ecological *representation* is addressed by the distribution of Mexican wolves across large portions of their historical range (per Parsons 1996) in the United States and Mexico. Habitat conditions vary between the MWEPA and Sierra Madre Occidental sites in both terrain and vegetation, as well as the abundance and distribution of prey. As previously discussed, historically Mexican wolves likely preyed upon a larger proportion of smaller prey in Mexico than the United States. Our data from the MWEPA and northern Sierra Madre Occidental currently show that Mexican wolves are likely to reeastablish this pattern, given the lack of elk in Mexico and lower deer densities in portions of the Sierra Madre Occidental compared to the MWEPA. We anticipate that genetically diverse wild populations in both reintroduction areas will be better able to respond to not the current range of habitat conditions, but also future changing conditions such as shifts in prey availability, drought, or other environmental fluctuations.

The results of Martínez-Meyer et al. 2017 and monitoring data from the MWEPA and northern Sierra Madre Occidental were used to inform Miller's (2017) exploration of whether natural connectivity via dispersing wolves is likely to occur between reintroduction sites and whether connectivity between these *redundant* populations is necessary for recovery of the Mexican wolf. We recognize benefits and drawbacks to either connected or isolated populations, as described in our 2010 Conservation Assessment. Miller 2017 assumed a low level of dispersal between the MWEPA and northern Sierra Madre Occidental population, and a slightly higher level of dispersal between the northern and southern Sierra Madre Occidental populations (see "Metapopulation Dynamics"). Modeling results predict that assumed levels of natural dispersal would not be sufficient to maintain the desired genetic *representation* for the Mexican wolf (Miller 2017, Scenario Set 1). Therefore, genetic management such as initial releases, translocations, and cross-fostering of pups is a necessary tool to achieve appropriate *representation* (Miller 2017, Scenario Set 2). This management is a form of artificial, or assisted, connectivity that will be necessary for at least portions of the recovery process.

<u>Conclusion</u>

The recovery of the Mexican wolf is well underway, with reintroduction occurring in the MWEPA in the United States and the northern Sierra Madre Occidental in Mexico. The MWEPA population, which has shown a positive growth trend in recent years, needs to continue to increase in size. Meanwhile, the release of wolves from captivity into the MWEPA needs to continue, in order to improve the genetic condition of the population. In Mexico, the establishing population will be strengthened by continued releases from captivity to both assist in population growth as well as improving the gene diversity of that population. The MWEPA and northern Sierra Madre Occidental sites, potentially supported by wolves in the southern Sierra Madre Occidental in the future, have the potential to provide *representation*, *resiliency*, and *redundancy* for the recovery of the Mexican wolf.

LITERATURE CITED

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. and G. H. Lukhart. 2007. Conservation and genetics of populations. Malden, MA: Blackwell Publishing Google Scholar. 2007.

Arizona Game and Fish Department [AGFD]. 2012. Arizona's State Wildlife Action Plan: 2012-2022. Arizona Game and Fish Department, Phoenix, Arizona.

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 Annual Report Reporting Period: January 1 – December 31, 2007.

Ballard, W. B., H. A. Whitlaw, B. F. Wakeling, R. L. Brown, J. C. DeVos, Jr., and M. C. Wallace. 2000. Survival of female elk in northern Arizona. Journal of Wildlife Management 64:500–504

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.

Barber-Meyer, S. M., L. D. Mech, and P. J. White. 2008. Elk calf survival and mortality following wolf restoration to Yellowstone National Park. Wildlife Monographs 169:1–30.

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.

Becker, M.S., R.A. Garrott, P.J. White, R. Jaffe, J.J. Borkowski, C.N. Gower, and E.J. Bergman. 2009. Wolf kill rates: predictably variable. In R.J. Garrott, P.J. White, and F.G.R. Watson, editors. The ecology of large mammals in central Yellowstone: sixteen years of integrated field studies. Academic Press, New York, pp 339-340.

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.

Beschta, R. L., and J. Ripple. 2013. Are wolves saving Yellowstone's aspen? A landscape-level test of a behaviorally mediated trophic cascade: comment. Ecology 93:1420–1425.

Bilyeu, D. M., D. J. Cooper, and N. T. Hobbs. 2008. Water tables constrain height recovery of willow on Yellowstone's northern range. Ecological Applications 18:80–92.

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.

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

Bowyer , R.T, V.C. Bleich, K.M. Stewart, J.C. Whiting, K.L. Monteith. 2014. Density dependence in ungulates: a review of causes and concepts with some clarifications." California Fish and Game 100(3):550-572.

Breck, S.W., B.M. Kluever, M. Panasci, J. Oakleaf, T. Johnson, W. Ballard, L. Howery, D.L. Bergman. 2011. Domestic calf mortality and producer detection rates in the Mexican wolf recovery area: Implications for livestock management and carnivore compensation schemes. Biological Conservation: online edition.

Brodie, J. F., E. Post, F. Watson, and J. Berger. 2012. Climate intensification of a trophic interaction: snow, herbivory, and aspen recruitment. Proceedings of the Royal Society B 279:1366–1370.

Brown, D. E., editor. 1988. The wolf in the southwest: the making of an endangered species. University of Arizona Press, Tucson, Arizona. 195 pp.

Carbone, C., and J. L. Gittleman. 2002. A common rule for the scaling of carnivore density. Science 295: 2273–2276.

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., M.K. Phillips, C. A. Lopez-Gonzalez. 2004. Spatial analysis of restoration potential and population viability of the wolf (Canis lupus) in the southwestern United States and northern Mexico. Final Report, Prepared for the Turner Endangered Species Fund. 70 pp.

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.

Caughley, G. 1994. Directions in Conservation Biology. Journal of Animal Ecology, 63(2), 215-244.

Chambers, S. M., S. R. Fain, B. Fazio, and M. Amaral. 2012. An account of the taxonomy of North American wolves from morphological and genetic analyses. North American Fauna. No.77. 67pp.

Creel, S., and D. Christianson. 2009. Wolf presence and increased willow consumption by Yellowstone elk: implications for trophic cascades. Ecology 90:2454–2466.

Creel, S., J. A. Winnie, D. Christianson, and S. Liley. 2008. Time and space in general models of antipredator responses: tests with wolves and elk. Animal Behavior 76(4):1139-1146

Cronin, M.A., A. Canovas, D. L. Bannasch, A. M. Oberbauer, J. F. Medrano. 2014. Single nucleotide polymorphism (SNP) variation of wolves (*Canis lupus*) in Southeast Alaska and comparison with wolves, dogs, and coyotes in North America. Journal of Heredity 106(1): 26–36.

Dekker, D., W. Dellinger, Bradford, and J.R. Gunson. 1995. Elk; and wolves in Jasper National Park, Alberta, from historical times to 1992. Pages 85-94 in L.N. Carbyn, S.H. Fritts, and D.R. Seip, editors. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute Occasional Publication Number 35.

Dellinger J. A., B. L. Ortman, T. D. Steury, J. Bohling, L. P. Waits. 2011. Food habits of red wolves during pup-rearing season. Southeastern Naturalist 10:731–740.

Deyoung, C.A., D.L. Drawe, T.E. Fulbright, D.G. Hewitt, S.W. Stedmen, D.R. Synatzske. 2009. Density dependence in deer populations: managing in variable environments. In Wildlife Science: Linking Ecological Theory and Management Applications.

Doak, D. F., G. K. Himes Boor, V. J. Bakker, W. F. Morris, A. Louthan, S. A. Morrison, A. Stanley, and L. B. Crowder. Recommendations for Improving Recovery Criteria under the US Endangered Species Act. BioScience 65: 189-199.

Eberhardt, L.L., P.J. White, R.A. Garrott, D.B. Houston. 2007. A seventy-year history of trends in Yellowstone's northern elk herd. The Journal of Wildlife Management 71:594-602.

Fitspatrick, B. M., J. R. Johnson, D. K. Kumpc, J. J. Smith, S. R. Voss, and H. B. Shaffer. 2010. Rapid spread of invasive genes into a threatened native species. PNAS 107: 3606-3610.

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

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

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

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

Fuller, T. K., 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.

Garcia Chavez, C., C. Aguilar Miguel, and C.A. López-González. 2017. Informe al USFWS sobre la depredación de ganado y abundancia por lobo mexicano reintroducidos en México. Universidad Autonoma de Queretaro.

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.

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.

González-Elizondo, M. S., M. González-Elizondo, L. Ruacho González, I.L. Lopez Enriquez, F.I. Retana Rentería, and J.A. Tena Flores. 2013. Ecosystems and Diversity of the Sierra Madre Occidental. Pages 204-211 in: Gottfried, Gerald J.; Ffolliott, Peter F.; Gebow, Brooke S.; Eskew, Lane G.; Collins, Loa C., comps. 2013. Merging science and management in a rapidly changing world: Biodiversity and management of the Madrean Archipelago III; 2012 May 1-5; Tucson, AZ. Proceedings. RMRS-P-67. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Goodman, D. 1987. The demography of chance extinction.

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

Hamlin, K. L. and J. A. Cunningham. 2009. Monitoring and assessment of wolf-ungulate interactions and population trends within the Greater Yellowstone Area, southwestern Montana, and Montana statewide: Final Report. Montana Department of Fish, Wildlife, and Parks, Wildlife Division, Helena, Montana, USA.

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, 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.

Heffelfinger, J. R., R. M. Nowak, and D. Paetkau. 2017. Clarifying historical range to aid recovery of the Mexican wolf. Journal of Wildlife Management. doi:10.1002/jwmg.21252.

Heffelfinger, J. 2006. Deer of the Southwest. A complete guide to the natural history, biology, and management of southwestern mule deer and white-tailed deer.

Hendricks, S. A., P. Charruau, J. P. Pollinger, R. Callas, P. Figura, and R. K. Wayne. 2015. Polyphyletic ancestry of historic gray wolves inhabiting U.S. Pacific states. Conservation Genetics 16:759–764.

Hendricks, S. A., P. R. Sesink Clee, R. J. Harrigan, J. P. Pollinger, A. H. Freedman, R. Callas, P. J. Figurae, and R. K. Wayne. 2016. Re-defining historical geographic range in species with sparse records: Implications for the Mexican wolf reintroduction program. Biological Conservation 194:48–57.

Hidalgo-Mihart, M.G., L. Cantú-Salazar, C.A. López-González, E. Martínez-Meyer, and A. González-Romero. 2001. Coyote (Canis latrans) food habits in a tropical deciduous forest of western Mexico. American Midland Naturalist 146:210-216.

Hoffmeister, D.F. 1986. The mammals of Arizona. University of Arizona Press.

Johnston, D. B., D. J. Cooper, and N. T. Hobbs. 2007. Elk browsing increases aboveground growth of water-stressed willows by modifying plant architecture. Oecologia 154:467–478.

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.

Kauffman, M. J., J. F. Brodie, and E. S. Jules. 2010. Are wolves saving Yellowstone's aspen? A landscape-level test of behaviorally mediated trophic cascade. Ecology 91:2742–2755.

Kauffman, M. J., J. F. Brodie, and E. S. Jules. 2013. Are wolves saving Yellowstone's aspen? A landscape-level test of behaviorally mediated trophic cascade: reply. Ecology 94:1425-1431.

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

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.

Liley, S.G., and S. Creel. 2008. What best explains vigilance in elk: characteristics of prey, predator, or the environment? Behavioral Ecology 19(2):245-254

López González, C. A. and N. E. Lara Díaz. 2016. It's complicated: Mexican wolf recovery efforts in Mexico. International Wolf, Fall 2016.

López González, C.A., N. E. Lara Díaz, C. Aguilar Miguel, and C. García Chávez. 2017. Mexican wolf in Mexico: Assessment of the conservation actions in the Sonora-Chihuahua area. Partial report submitted to Arizona Game and Fish Department. 126 pp.

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, J.A. Vucetich, L.D. Mech, D.R. Stahler, and C Packer. 2009. 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

Mao, J. S., M. S. Boyce, D. W. Smith, F. J. Singer, D. J. Vales, J. M. Vore, and E. H. Merrill. 2005. Habitat selection by elk before and after wolf reintroduction into Yellowstone National Park. Journal of Wildlife Management 69:1691– 1707.

Martínez-Meyer, E., A. González-Bernal, J. A. Velasco, T. L. Swetnam, Z. Y. González-Saucedo, J. Servín, C. A. López González, N. E. Lara Díaz, C. Aguilar Miguel, C. Chávez García, and J. K. Oakleaf. 2017. Mexican wolf habitat suitability analysis in historical range in the Southwestern US and Mexico. Final report, April 2017. 86 pp.

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

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

Mech, L. D., 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. 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.

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

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

Middleton, A.D., M.J. Kauffman, D.E. McWhirter, M.D. Jimenez, R.C. Cook, J.G. Cook, S.E. Albeke, H. Sawyer, and P.J. White. 2013. Linking anti-predator behaviour to prey demography reveals limited risk effects of an actively hunting large carnivore. Ecology Letters 16(8):1023-1030.

Miller, P.S. 2017. Population viability analysis for the Mexican wolf (Canis lupus baileyi): Integrating wild and captive populations in a metapopulation risk assessment model for recovery planning. Prepared for U.S. Fish and Wildlife Service, Albuquerque, NM. .

Mills, L.S. 2007. Conservation of Wildlife Populations: Demography, Genetics, and Management. Blackwell Publishing, Malden, MA.

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.

National Research Council. 1997. *Wolves, Bears, and Their Prey in Alaska: Biological and Social Challenges in Wildlife Management*. The National Academies Press, Washington D.C.

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

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.

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.

Oakleaf, J.K., D.L Murray, J.R. Oakleaf, E.E. Bangs, C.M. Mack, D.W. Smith, J.A. Fontaine, M.D. Jimenez, T.J. Meier, C.C. Niemeyer. 2006. Habitat selection by recolonizing wolves in the northern Rocky Mountains of the United States. The Journal of Wildlife Management: 70(2).

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.

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.

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, 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.

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.

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

Ripple, W. J. and R. L. Beschta. Trophic cascades in Yellowstone: The first 15 years after wolf reintroduction. 2011. Biological Conservation (2011), doi:10.1016/j.biocon.2011.11.005

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

Salvídar Burrola, L. L. 2015. Hábitos alimentarios del lobo Mexicano (*Canis lupus baileyi*) en el noroeste de Chihuahua. B.S. Thesis (Tesis). Universidad Autónoma de Ciudad Juárez, Chihuahua. 62 pp.

Schwartz, C. C., M. A. Haroldson, G. C. White, R. B. Harris, S. Cherry, K. A. Keating, D. Moody, and C. Servheen. 2006. Temporal, spatial, and environmental influences on the demographics of grizzly bears in the Greater Yellowstone Ecosystem. Wildlife Monographs 161:1–68.

Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). 2010. NORMA Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. Secretaría de Medio Ambiente y Recursos Naturales, Jueves 30 de diciembre de 2010. Estados Unidos Mexicanos.

Seip, D. R. 1995. Introduction to wolf-prey interactions. In L. N. Carbyn, S. H. Fritts, and D. R. Seip, eds. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institite, University of Alberta, Edmonton, Canada.

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.

Short, H.L. 1979. Deer in Arizona and New Mexico: Their ecology and a theory explaining recent population decreases. General Technical Report RM-70. Rocky Mountain Forest and Range Experiment Station. Forest Service, U.S. Department of Agriculture.

Siminski, P. and E. Spevak. 2016. 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. 93pp.

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.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.

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.

Soule, M., M. Gilpin, W. Conway, and T. Foose. 1986. The Millenium Ark: How Long a Voyage, How Many Staterooms, How Many Passengers? Zoo Biology 5:101-113.

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.

Tercek, M. T., R. Stottlemyer, and R. Renkin. 2010. Bottom-up factors influencing riparian willow recovery in Yellowstone National Park. Western North American Naturalist 70:387–399.

Tyers, D. B. 2006. Moose population history on the northern Yellowstone winter range. Alces 42:133–149.

U.S. Fish and Wildlife Service [USFWS]. 2002. 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]. 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]. 2006. 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]. 2008. Mexican wolf recovery program: Mexican wolf reintroduction progress report 11. Technical Report. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 2009. Mexican wolf recovery program: Mexican wolf reintroduction progress report 12. Technical Report. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS 2010]. Mexican Wolf Conservation Assessment. Region 2, Albuquerque, New Mexico, USA.

U.S. Fish and Wildlife Service [USFWS]. 2014. Final environmental impact statement for the proposed revision to the regulations for the nonessential experimental population of the Mexican wolf. Albuquerque, New Mexico. Available online at https://www.fws.gov/southwest/es/mexicanwolf/pdf/EIS_for_the_Proposed_Revision_to_the_Regulations_for_the_Nonessential_Experimental_Population_of_the_Mexican_Wolf.pdf

U.S. Fish and Wildlife Service [USFWS]. 2015. Mexican Wolf Recovery Program: Progress Report #18. Reporting period: January 1 – December 31, 2015. Albuquerque, New Mexico. Available online at https://www.fws.gov/southwest/es/mexicanwolf/documents.cfm

U.S. Fish and Wildlife Service [USFWS]. 2016. Recovery Plan Development and Implementation. Memorandum from Deputy Director to Regional Directors, September 21, 2016.

U.S. Fish and Wildlife Service [USFWS]. 2017a. News release: 2016 Mexican wolf population survey reveal gains for experimental population. February 17, 2017. Available online at https://www.fws.gov/southwest/es/mexicanwolf/pdf/NR_2016_Mexican_Wolf_Annual_Count.pdf

U.S. Fish and Wildlife Service [USFWS]. 2017b. Mexican wolf population information. Available online at https://www.fws.gov/southwest/es/mexicanwolf/MWPS.cfm

Unsworth, J. W., F.D. Pac, G. C. White, and R. M. Bartmann. 1999. Mule deer survival in Colorado, Idaho, and Montana. The Journal of Wildlife Management 63:315–326.

Valdez, R., J. C. Guzmán-Aranda, F. J. Abarca, L. A. Tarango- Arámbula, and F. Clemente Sánchez. 2006. Wildlife Conservation and Management in Mexico. Wildlife Society Bulletin 34:270-282.

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.

Wahlberg, M.; Triepke, F.J.; Robbie, W.; Stringer, S.H.; Vandencriesche, D., Muldavin, E.; Malusa, J.; and P. Shahani. 2016. DRAFT Ecological Response Units of the Southwestern United States. US Department of Agriculture, Forest SErvice, Southwestern Region. 197 pp.

White, P.J. and R.A. Garrott. 2005. Northern Yellowstone elk after wolf restoration. Wildlife Society Bulletin 33:942-955.

Whiteley, A. R., S. W. Fitzpatrick, W. C. Funk, and D. A. Tallmon. 2015. Genetic rescue to the rescue. Trends in Ecology and Evolution 30: 42–49.

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.

Wolf, E. C., D. J. Cooper, and N. T. Hobbs. 2007. Hydrologic regime and herbivory stabilize an alternative state in Yellowstone National Park. Ecological Applications 17:1572–1587.

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

APPENDIX A. Population viability analysis for the Mexican wolf (Canis lupus baileyi): Integrating wild and captive populations in a metapopulation risk assessment model for recovery planning

APPENDIX B. Mexican wolf habitat suitability analysis in historical range in the Southwestern US and Mexico. Final Report.

The Fish and Wildlife Service created an informational packet of the following materials related to the Draft Mexican Wolf Recovery Plan, First Revision. We have broken the packet into smaller sections to allow for easier readability.

The contents of the Packet are as follows:

- Draft Biological Report for the Mexican Wolf, May 1, 2017 version
- Population Viability Analysis for the Mexican Wolf (05/01/17) and Addendum (05/22/17)
- Mexican Wolf Habitat Suitability Analysis in Historical Range in Southwestern US and Mexico, April 2017 version
- 5 peer reviews received on the above documents

The U.S. Fish and Wildlife Service provided the above versions of the Draft Biological Report and two supporting analyses, "Population Viability Analysis for the Mexican Wolf" and "Mexican Wolf Habitat Suitability Analysis in Historical Range in Southwestern US and Mexico", followed by an addendum to the population viability analysis, for peer review from May 2, 2017 to June 2, 2017. Five peer reviewers provided comments to the Service through an independent contractor, Environmental Management and Planning Solutions, Inc.

FWS is providing this packet as supplemental background information to the public during the public comment period for the Draft Mexican Wolf Recovery Plan, First Revision. Peer reviews are anonymous at this time but FWS will provide peer reviewers names and affiliations when the recovery plan and biological report have been finalized.