WHITE PAPER: SIGNIFICANCE OF THE WESTERN POPULATION(S)
OF THE CACTUS FERRUGINOUS PYGMY-OWL
(December 2, 2003)

INTRODUCTION

This paper explores the significance of the cactus ferruginous pygmy-owl distinct population segment (DPS) as listed under the Endangered Species Act to the taxon as a whole. This is done by a progressive assessment of potential significance issues starting with the significance of the Arizona DPS to the Sonoran Desert Biome, then to the western population (WP), and finally to the taxon as a whole (See Table 1). New information or information not used during the 1997 listing is **bolded** within the text of this document. Appendix 4 contains all literature cited in the body of the paper and in all appendices.

The purpose of the paper is to assist the FWS in addressing the 9th Circuit Court of Appeals ruling which found that the Fish and Wildlife Service (FWS) was "arbitrary and capricious" in its determination to list the Arizona portion of the subspecies' range as an endangered DPS. Specifically, the 9th Circuit found that the "significance" portion of the DPS determination was insufficient. Both the District and Appellate courts deferred to the FWS' DPS policy and upheld the Service's finding of discreteness. (See Appendix 1 for a discussion of the DPS policy and Appendix 2 for a discussion of discreteness which includes information that was not available when the 1997 determination was made.)

ANALYSIS OF SIGNIFICANCE OF THE ARIZONA DPS

1. Unusual or Unique Ecological Setting - Three quarters of the distribution of the pygmy-owl occurs within tropical and sub-tropical biotic communities, including the eastern population (EP) which occupies mesquite forest, riparian forest, thorn forest, tropical deciduous forest, heavy riparian forest, and areas more tropical in nature, including cypress groves (**Cartron et al. 2000b, Proudfoot and Johnson 2000,** Leopold 1950), and southern Sonora, Sinaloa, and Nayarit where pygmy-owls occur within the tropical Sinaloan thornscrub and Sinaloan deciduous forest community types and associated riparian communities (**Leopold 1950,** Brown 1994, **Phillips and Comus 2000**).

Only one quarter of the distribution, including the Arizona DPS, falls within desert biotic communities. As a result, the biotic communities occupied by the Arizona DPS are unique for the taxon. The Arizona DPS extends farther north in latitude than the remainder of the pygmy-owl's range. As a result, conditions within the Arizona DPS tend to be cooler and drier. Climate in the area occupied by the Arizona DPS is classified as arid to very arid, while those areas outside of Arizona are typically warmer, moister, and of a tropical or sub-tropical climate. Additionally, soil type differs and is dominated by regosols within the Arizona DPS. In contrast, other areas within the range of the pygmy-owl are primarily solonchak, vertisol, and xerosol soils (http://mexico channel.net/maps). Soil type often contributes to the vegetation type that occurs on a site. As expected, vegetation communities also differ. The Arizona DPS is found within

Sonoran Desert scrub or Semidesert Grassland biotic communities and associated riparian and xeroriparian communities (Cartron et al. 2000b, Proudfoot and Johnson 2000) (see Figure 2).

Only in northern Sonora does the ecological setting exhibit similar ecological conditions to the range of the Arizona DPS with regard to vegetation, climate, soils, etc. (Leopold 1950, Brown 1994, Phillips and Comus 2000, http://mexico channel.net/maps). However, land use activities in northern Sonora have created and continue to create an ecological setting that is very different than that occupied by the Arizona DPS. In Mexico, millions of acres of Sonoran Desert and thornscrub are being converted to buffelgrass (*Pennisetum ciliaris*) which represents both a direct and an indirect loss of habitat because of invasion into adjacent areas and increased fire frequency and intensity (Burquez-Montijo et al. 2002) (see Figure 3).

Buffelgrass occurs in areas purposely converted from native vegetation communities to buffelgrass plantations, and it is also invading into and becoming dominant in other areas of native vegetation. Conversion is achieved by first clearing the native vegetation by mechanical means, and then seeding with buffelgrass. The occurrence of buffelgrass is changing the ecology of these areas by increasing the frequency and intensity of fire, which in turn is resulting in the conversion of native vegetation communities into savanna grasslands. The consequent elimination of trees, shrubs, and columnar cacti from these areas is a serious threat to the survival of the pygmy-owl, as these vegetation components are necessary for roosting, nesting, protection from predators, and thermal regulation. Birds are most affected by loss of vegetation, especially of plant species such as cactus that area highly susceptible to fire. Cavity nesting obligates such as small owls, woodpeckers, and purple martins suffer when saguaros are lost to fire (Esque and Schwalbe 2002).

In Sonora, Mexico, 1.6 million ha of desert vegetation has been converted to bufflegrass pasture (about 10% of the state's area)(Burquez-Montijo et al. 2002). Up to 1/3 of the state's area has been targeted for conversion to buffelgrass (Navarro 1988 in Williams and Baruch 2000). This acreage is in addition to those areas that have also been cleared or converted for agriculture and urban development. Burquez and Yrizar (1997) state that "Given the government subsidies to establish exotic introduced grasslands, to maintain large cattle herds, and to support marginal cattle ranching, the desert and thornscrub in Sonora will probably be replaced in the near term by ecosystems with significantly lower species diversity and reduced structural complexity, unless control measures are implemented." Such replacement is and will continue to affect pygmy-owl prey base and habitat availability.

In Arizona, many of the areas suitable for buffelgrass are managed as FWS wildlife refuges, national monuments and parks, or occur on the Tohono O'odham Nation, where purposeful conversions are unlikely to occur, although non-native grass invasions have occurred. These non-native grasses have increased the frequency and intensity of fires in the Sonoran Desert scrub of Arizona. Efforts are underway in some of these areas to restore areas where exotic plant invasions have occurred. Thus, ecosystem conditions are less likely to be altered in Arizona, at least with regard to the severity of ecological impacts of vegetation community conversion for livestock and agriculture that is occurring in Mexico. This results in an unusual ecological setting for the Arizona DPS when contrasted with Mexico. Other impacts to the ecological setting are occurring within the Arizona DPS (primarily related to urbanization), but the large-scale, purposeful conversion of native vegetation communities to homogenous, unsuitable landscapes is unlikely. Pygmy-owl research efforts are ongoing with the objective of improved management and protection. In the not-so-distant future, the Arizona DPS may represent the majority of pygmy-owls occupying the Sonoran Desert biome, which is a unique ecological setting for pygmy-owls. (See Appendix 3 for a more detailed discussion on threats related to buffelgrass conversion).

In summary, the Arizona DPS occurs in arid desert biotic communities, which comprise only one quarter of the range of the species. Although pygmy-owls in northern Sonora also exist in these biotic communities, much of the habitat there has or will be converted to buffelgrass plantations, agricultural fields, and urban areas. This large-scale loss of Sonoran Desert biome communities in northern Sonora places the Arizona DPS in a unique and unusual ecological setting.

2. Significant Gap in the Range of the Taxon - The range of the pygmy-owl is clearly divided into western and eastern population segments of approximately the same size, based on geographic and genetic separation (AOU 1957, Cartron et al. 2000a, Proudfoot and Johnson 2000, Proudfoot and Slack 2001) (see Figure 1). Thus, the western population represents approximately 50% of the range of the taxon. Within the WP, further physical separation of the taxon occurs in central Sonora. Flesch (2003) indicated that low pygmy-owl abundance in central Sonora was due to a lack of suitable habitat. This lack of pygmy-owl habitat was attributed to low abundance of columnar cacti (and the nesting cavities they provide) along the ecotone between desert scrub and thornscrub vegetation communities. This ecotonal separation is exacerbated by the conversion of native vegetation to agricultural crops and buffelgrass pastures for livestock grazing (Flesch 2003)(see Figure 4 and Figure 5). Other land uses also contribute to the separation. Completion of the Huites Dam on the Rio Fuerte, Sinaloa, in 1995, flooded 23,000 acres of tropical deciduous forest and facilitated a more than doubling of agriculture acreage in the Rio Fuerte Valley of northern Sinaloa (see Figure 6).

The area north of this separation, including the Arizona DPS, accounts for approximately 50% of the WP and, therefore, approximately 25% of the range of the taxon. Loss of the Arizona population at the northern end of this WP separation would create a gap in the range of the taxon under the definition upheld by the 9th Circuit ("We defer to the FWS' interpretation of a "gap at the end of the fence" because it is not plainly erroneous. Even the loss of a peripheral population, however small, would create an empty geographic space in the range of the taxon."(9th Circuit Opinion - CV 00-0903 SRB). This gap is important to the taxon as a whole. The historical range of the pygmy-owl in Arizona extended north of Phoenix to the New River area (Monson 1998). Therefore, the loss of the Arizona population would represent the loss

of approximately 15% of the historical range of the western population segment. However, it represents 50% - 60% of the historical range of the pygmy-owl within the Sonoran Desert biome. This percentage is meaningful when looking at the range of the taxon because it represents a major portion of the historical range from the perspectives of both geography (size of the area and percentage of occupancy within the unique Sonoran Desert biome ecological setting) (see Figure 2) and population (a peripheral population's contribution to genetic diversity of the species).

A gap in the historical and current range of the pygmy-owl, which would be created by the loss of the Arizona DPS, is consequential to the taxon because it could reduce the genetic variability of the taxon. Given the genetic and geographic separation between the EP and the WP (Figure 1) and the ecotonal and habitat division of the WP (Figure 4, Figure 5, and Figure 6), the Arizona DPS could represents an important source of genetic diversity within the range of the taxon. Genetic divergence tends to occur at the periphery of a species' range (Lesica and Allendorf 1995). This genetic divergence allows adaptation of the species as a whole in the face of environmental change. Loss of genetic diversity translates into a loss of fitness (reproductive success) for the species (Meffe and Carroll 1997).

The peripheral nature of the Arizona DPS increases the potential for the population to diverge from populations in Sonora and Sinaloa. Although there is not a marked genetic difference between the Arizona DPS and the rest of the WP, as a peripheral population, the loss of the Arizona DPS could likely be meaningful with regard to genetic divergence. Because peripheral populations are often isolated from core populations, peripheral populations may become genetically distinct because of genetic drift and divergent natural selection (Lesica and Allendorf 1995). Hence, protection and management of peripheral populations may be important to the survival and evolution of species. Maintaining genetic diversity within the WP and the taxon as a whole will be more important in the face of documented land use changes in Mexico (Burquez and Yrizar 1997). Resistance to environmental change and genetic distinction often allow peripheral populations to persist when core populations are extirpated (Channell and Lomolino 2000a, 2000b, Lomolino and Channell 1995). In the face of changing environmental conditions, what constitutes a peripheral population today could be the center of the species' range in the future (Nielsen et al. 2001). With the widespread impacts to native vegetation in Mexico, this may hold true for the Arizona DPS. Peripheral populations survive more frequently than do core populations when species undergo dramatic reductions in their range (>75%; Channell and Lomolino 2000a), again an important issue when considering land use activities in Mexico.

In summary, the loss of the Arizona population would represent a gap in the range of the taxon and could represent the loss of genetic variability for the taxon as a whole. Proudfoot and Slack (2001) present the most current and extensive work on the genetics of the pygmy-owl. They found that there were distinct differences between the Arizona and Texas populations of the pygmy-owl. Their work also showed genetic differences between the eastern and western Mexico populations. The bimodal distribution of pygmy-owls in central Sonora documented by Flesch (2003) indicates a physical barrier which could be resulting in further genetic isolation. The Arizona population represents a peripheral population, the loss of which could result in the reduction of genetic variability, which in turn would reduce the species ability to adapt to changing environmental conditions and increase the likelihood of extinction.

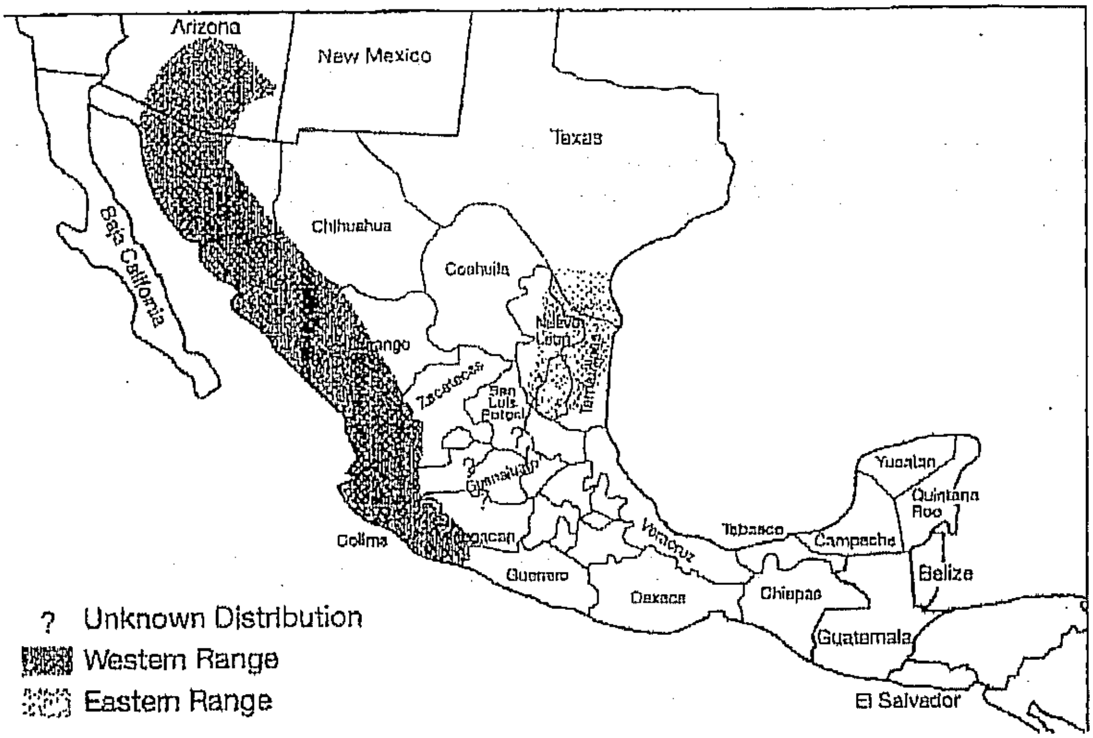

Figure 1. Cactus ferruginous pygmy-owl distribution in Mexico and the United States (Cartron et al. 2000a). Note that more recent genetic information indicates that the western population only includes Arizona, Sonora, and Sinaloa, and that the eastern population extends further along the Atlantic slope to central Panama (Proudfoot and Slack 2001).

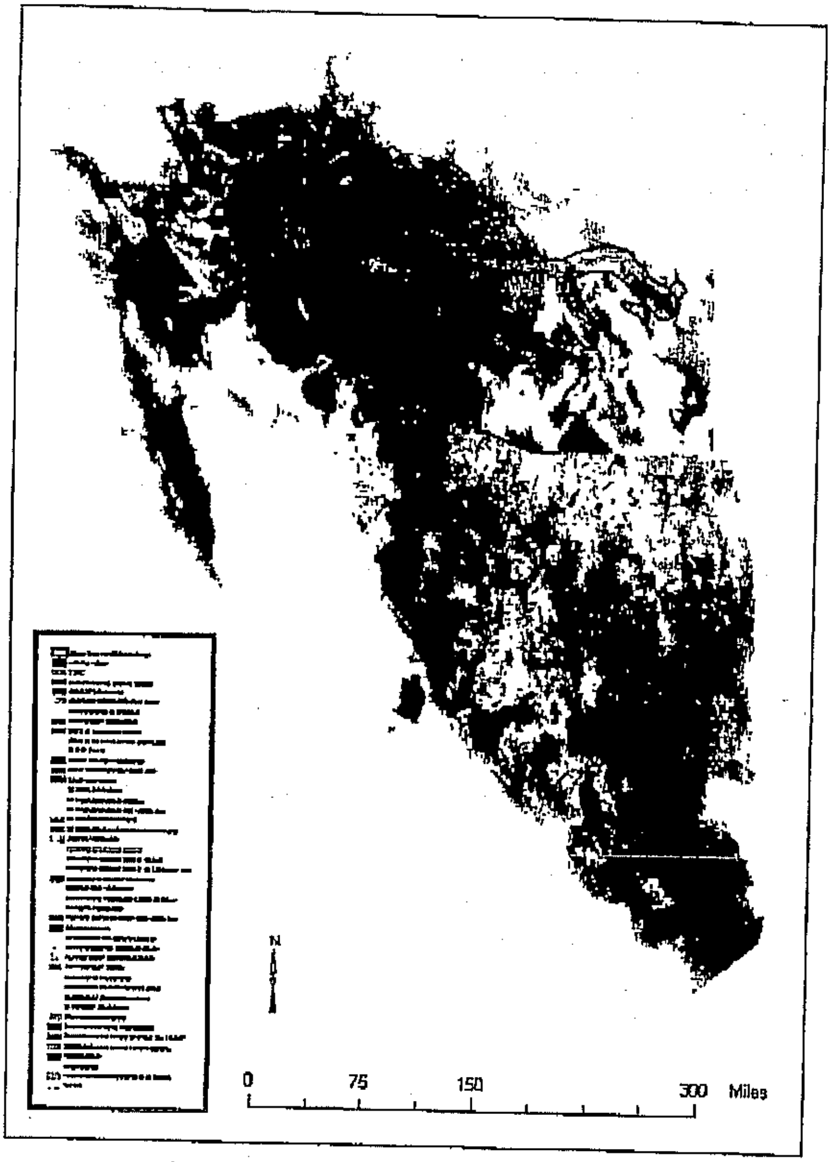

Figure 2. Vegetation communities in southern Arizona and northwestern Arizona. The red line shows the historical range of the pygmy-owl in Arizona. The Sonoran Desert scrub and semidesert grassland communities are shown in orange and yellow, respectively.

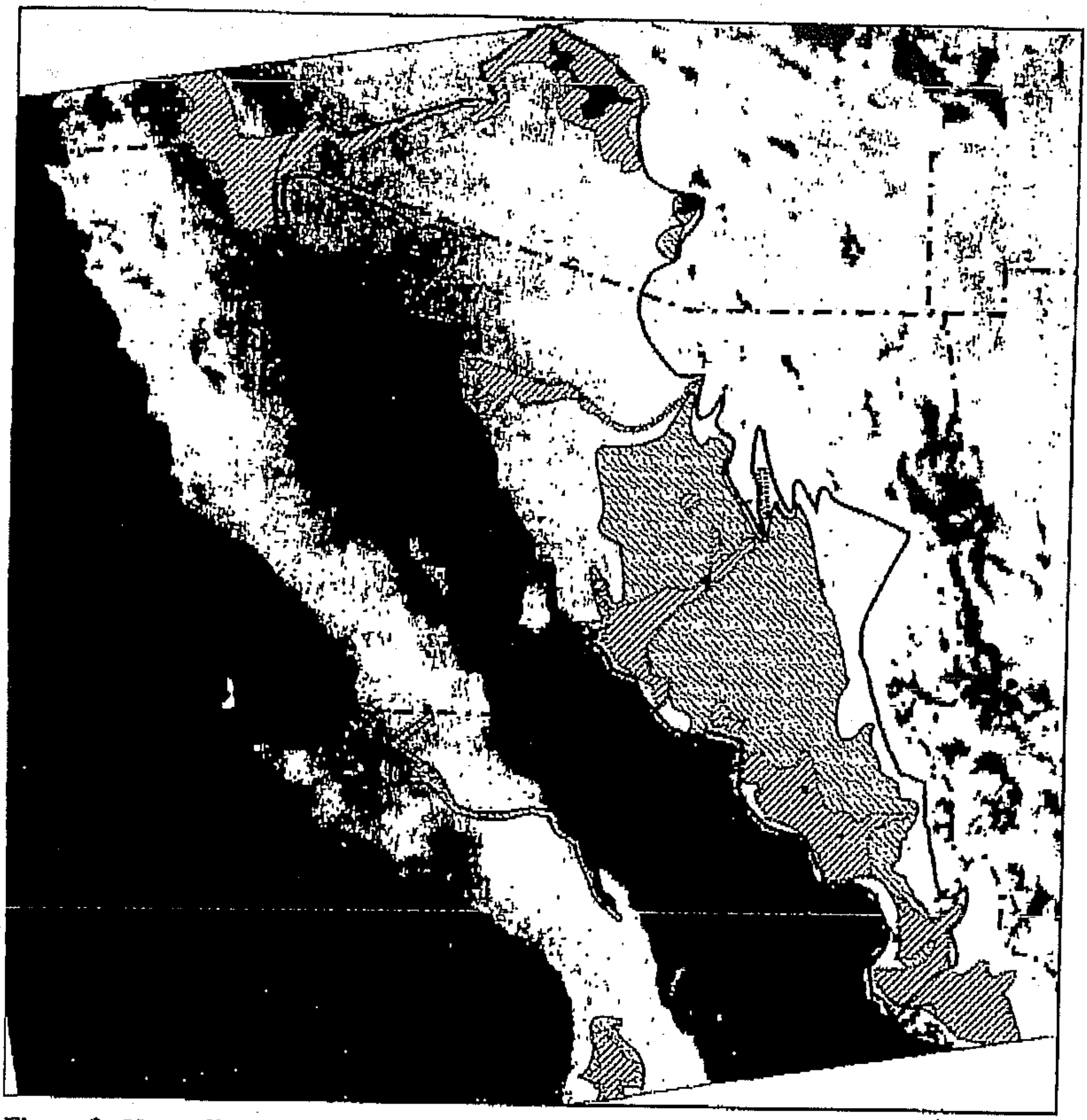

Figure 3. Normalized vegetation index image for northwestern Mexico–southwestern USA showing the approximate range of distribution of buffelgrass (inside solid line), the areas where buffelgrass forms extensive stands replacing the Sonoran Desert scrub (shaded area), and the major irrigation districts where complete ecosystem conversion has occurred (inside dotted line). Background image from Arizona Regional Image Archive. (Búrquez-Montijo et al. 2002).

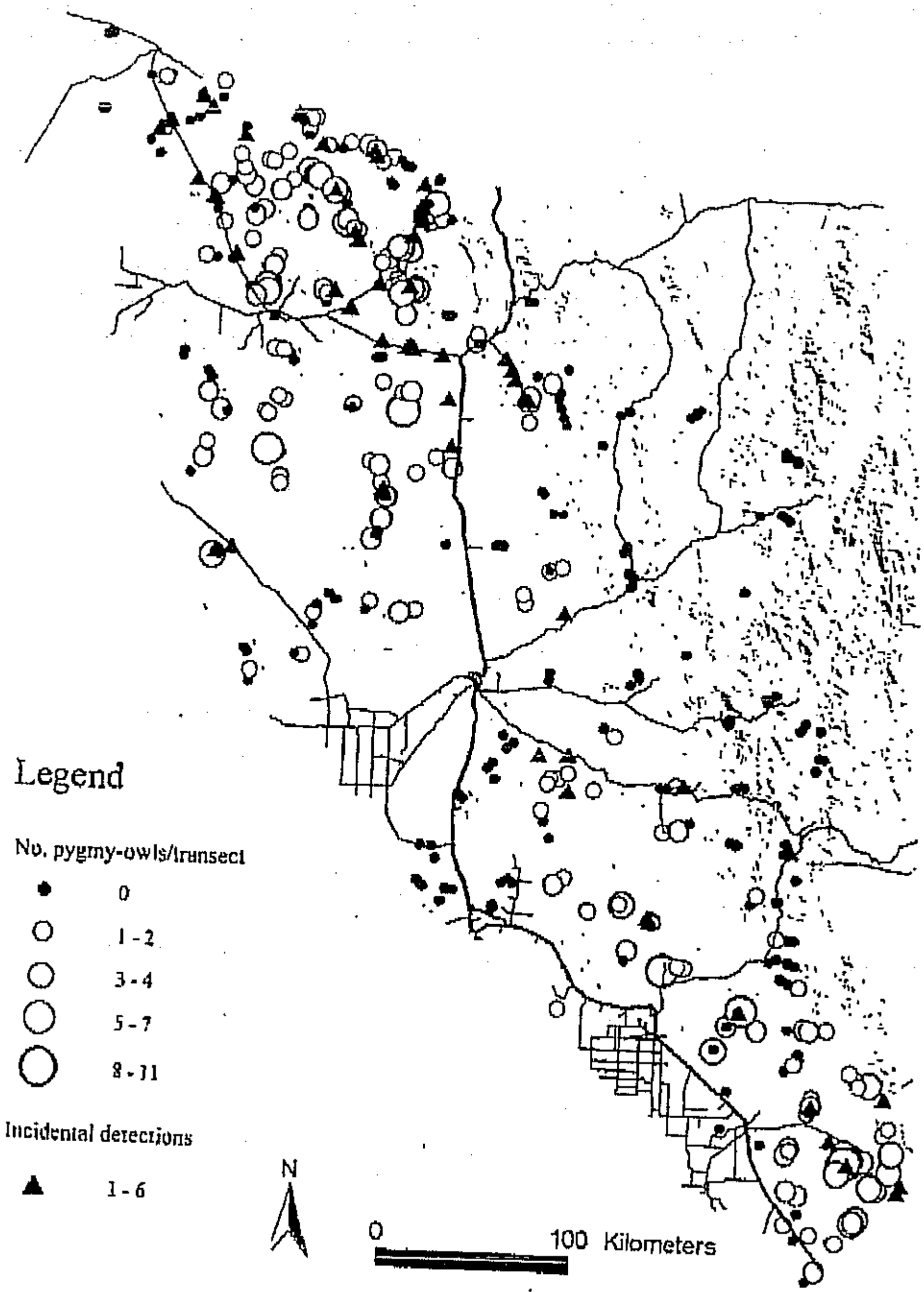

Figure 4. Distribution and abundance (number detected/transect) of ferruginous pygmy-owls in Sonora, Mexico (2000-01). (Flesch 2003)

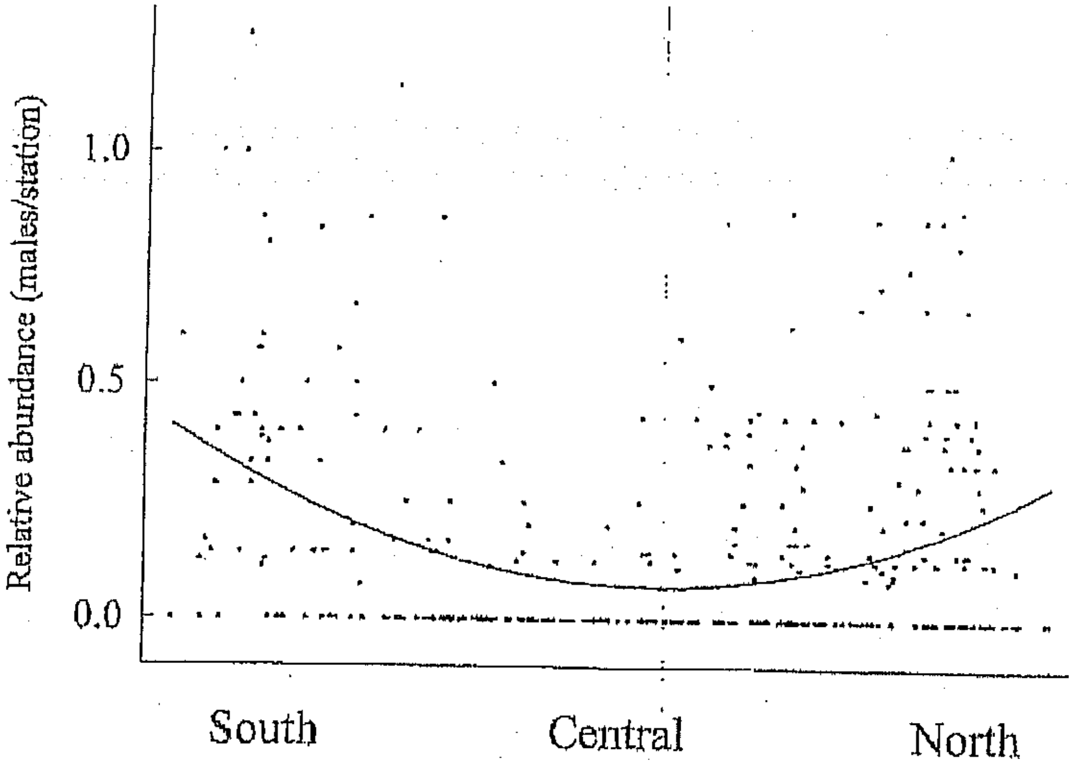

Figure 5. Relative abundance (number of males/station) of ferruginous pygmy-owls varied with latitude across Sonora, Mexico 2000-01 (from Flesch 2003).

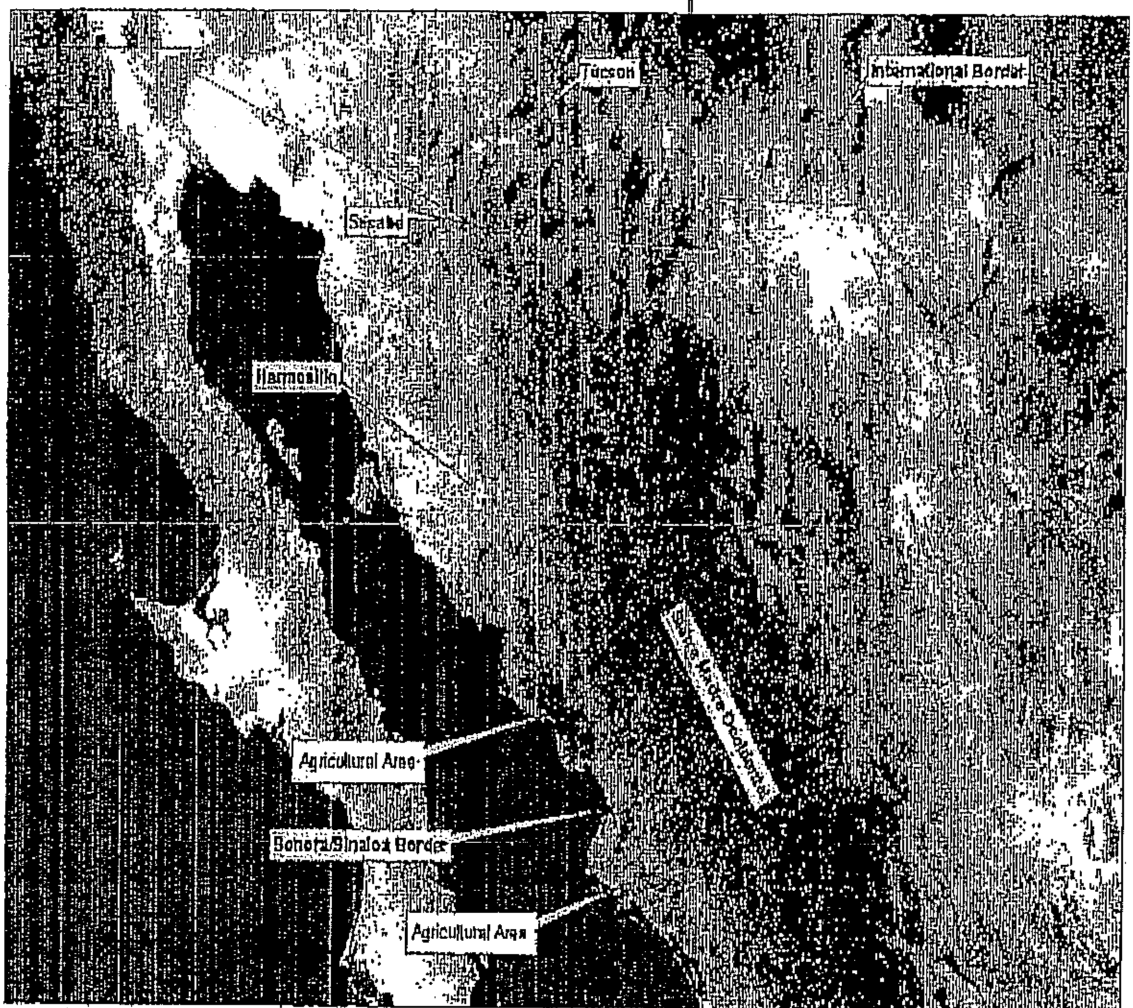

Figure 6. Aerial photograph of northwestern Mexico. (Http://www.conabio.gob.mx/informacion/geo_espano/doctos/imagenmcclia_febrero2002.html) México: Imagen desde el espacio Comisión Nacional para el Conocimiento y Uso de la Biodiversidad Mosaico 2002 de imágenes Modis sin nubes del satélite Terra, bandas 1,4,3 (RGB), resolución espacial 250 metros, sobre un modelo digital de terreno.

Table 1. Summary of discreteness and significance factors for the cactus ferruginous pygmy-owl in 2003.

Population Segment	Discreteness - markedly separated by physical, physiological, ecological, or behavioral factors	Discreteness - delimited by international boundary; significant differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms	Significance - unique ecological setting for taxon	Significance - loss would result in significant gap in the range of the taxon	Significance - differs markedly in genetic characteristics
Arizona Distinct Population Segment	Physically separated from Eastern Population (EP) (Sierra Madre Occidental and Oriental and Mexican Plateau); 2) ecologically separated from EP (vegetation, climate, soils, precipitation); 3) genetically and morphologically separated from EP	Delimited by international boundary with Mexico based on differences in conservation status, habitat management, and regulatory mechanisms	Ecologically different than EP (vegetation, soils, precipitation, climate); 2) unique from rest of WP (different land uses and protection)	1) Represents approximately 50-60 % of SDB; 15 % of WPS; 2) peripheral population, which is important to species persistence in changing environments	1) Genetically different than EP; 2) not genetically different than rest of WP

Population Segment	Discreteness – markedly separated by physical, physiological, ecological, or behavioral factors	Discreteness – delimited by international boundary, significant differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms	Significance – unique ecological setting for taxon	Significance – loss would result in significant gap in the range of the taxon	Significance – differs markedly in genetic characteristics
Sonoran Desert Biome (SDB)	1) Physically separated from EP (Sierra Madre Occidental and Oriental and Mexican Plateau); 2) ecologically separated from EP (vegetation, climate, soils, precipitation); 3) genetically and morphologically separated from EP; 4) physically separated from rest of WP (lack of habitat in central Sonora); 5) ecologically separated from rest of WP (vegetation)	None	1) Ecologically different than EP (vegetation, soils, precipitation, climate); 2) ecologically different than rest of WP (vegetation); 3) unique from rest of WP (loss of native vegetation)	1) Represents approximately 25% of range of entire taxon (including EP); approximately 50% of WP	1) Genetically different than EP; 2) not genetically different than rest of WP

Population Segment	Discreteness—markedly separated by physical, physiological, ecological, or behavioral factors	Discreteness—delimited by international boundary; significant differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms	Significance—unique ecological setting for taxon	Significance—loss would result in a significant gap in the range of the taxon	Significance—differs markedly in genetic characteristics
Western Population (WP)	1) Physically separated from EP (Sierra Madre Occidental and Oriental and Mexican Plateau); 2) ecologically separated from EP (vegetation, climate, soils, precipitation); 3) genetically and morphologically separated from EP	None	Ecologically different than EP (vegetation, soils, precipitation, climate)	Represents approximately 50% percent of the total range of the taxon	genetically different than EP

Appendix 1. THE DPS POLICY (61 FR 4722 - 4725)

Discreteness: A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions:

1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.

2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act.

Significance: If a population segment is considered discrete under one or more of the above conditions, its biological and ecological significance will then be considered in light of Congressional guidance. In carrying out this examination, the FWS considers available scientific evidence of the discrete population segment's importance to the taxon to which it belongs. This consideration may include, but is not limited to, the following:

1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon,

2. Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon,

3. Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, or

4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

Appendix 2. Discreteness of the Arizona DPS

International Boundary - In their August 9, 2003 opinion, the court found that the FWS' determination that pygmy-owls were "extremely limited in distribution" in Arizona, but existed in greater numbers in northwestern Mexico (Listing Rule, 62 Fed. Reg. At 10,740), was an adequate exercise of agency expertise. Thus, the court held that the FWS' use of the international border, in light of differences in conservation status, to satisfy the discreteness element of the DPS Policy was not arbitrary (9th Circuit Opinion - CV 00-0903 SRB).

Since the 1997 listing, additional information is available that would apply to a determination of discreteness. The difference in conservation status has been further documented. Extensive pygmy-owl surveys conducted in 2000 and 2001 in Sonora, Mexico (Flesch 2003) and ongoing surveys in Arizona (Abbate et al. 1999, 2000) have documented relatively high numbers of pygmy-owls in Sonora and relatively few in Arizona. Based on this new information, the argument for discreteness based on differences in conservation status is stronger today than it was in 1997.

Information related to the other differences across the international boundary are also applicable to the Arizona pygmy-owl DPS. While not argued strongly in the 1997 listing, information is available to support these additional differences. For example, substantial differences occur in pygmy-owl habitat management. Management that would support or maintain pygmy-owl habitat in Mexico is absent. In fact, the Mexican government promotes and supports the conversion of pygmy-owl habitat to agricultural uses and buffelgrass for livestock grazing. Areas previously set aside for conservation have been opened to resource extraction and urban development (Burquez and Martinez Yrizar 1997). In Arizona, pygmy-owls occupy areas that are FWS Wildlife Refuges and National Park Service lands where resource conservation is the primary objective. Pygmy-owl habitat occurring on Bureau of Land Management or Forest Service lands is managed under a multiple-use mandate, in contrast to the single-use management prevalent in Mexico. Local Arizona municipalities have native plant protection ordinances which directly benefit pygmy-owl habitat.

Differences in regulation across international boundaries can also be used to define discreteness. The pygmy-owl does not receive regulatory protection under Mexico's endangered, threatened, and special status species document (NORMA 2001). In Arizona, the pygmy-owl receives limited Federal regulatory protection under the Migratory Bird Treaty Act and State regulatory protection under State wildlife laws (ARS Title 17).

The western population of pygmy-owls, including the Arizona DPS, is clearly discrete from the eastern population. In the literature, the pygmy-owl was divided into two geographically distinct populations (AOU 1957). The eastern population (Texas, Tamaulipas, Nuevo Leon, and Veracruz) was separated from the western population (Arizona, Sonora, Sinaloa, and Nayarit) by the mountains and highlands of the Sierra Madre Occidental and Oriental and the Mexican Plateau, including the Chihuahuan desert (AOU 1957, **Proudfoot and Johnson 2000, Cartron** populations, the western population (WP) occurring in Arizona, Sonora, and Sinaloa and the eastern population (EP) occurring in Chiapas, Jalisco, Michoacan, Nayarit, Oaxaca, Tabasco, Tamaulipas, Texas, Veracruz, and Yucatan (**Proudfoot and Slack 2001**). While some unifying characteristics can be found in areas occupied by the two populations, overall ecological conditions are different. The EP occupies more humid, forested vegetation communities. The WP occurs in drier, more desert-like conditions and vegetation communities. Morphological differences also occur between the EP and WP. Pygmy-owls from the EP tend to be more rufous in their coloration and are darker and more richly colored. WP pygmy-owls tend to be paler and more gray (Ridgeway 1914, van Rossem 1937, AOU 1957, Phillips et. al. 1966, **Proudfoot and Johnson 2000**)

Appendix 3: Effects of buffelgrass in cactus ferruginous pygmy-owl habitat in Northwest Mexico and Arizona.

Buffelgrass is one of many invasive plant and animal species that are an increasing threat to a variety of species and communities in the Southwest (Minckley and Deacon 1991; Rosen *et al.*, 1994, Bahre 1995, Stromberg and Chew 1997). The effects of bufflegrass on natural environments are most apparent in Sonoran Desert scrub, Sinaloan thornscrub, and tropical deciduous forests in Sonora; however, the species is spreading rapidly in the Sonoran Desert of Arizona, as well. Biological invasions, such as that of buffelgrass, are now rated among the top ten threats to the integrity of Sonoran Desert ecosystems (Nabhan 2000). Biological invasions are second only to land-use changes in causing species extinctions (D'Antonio and Vitousek 1992). Desert habitats are described as being relatively "open" to colonization (by exotics) compared with grasslands and woodlands because ground cover is so sparse (Esque and Schwalbe 2002). Buffelgrass occurs in areas purposely converted from native vegetation communities to buffelgrass plantations, and it is also invading into and becoming dominant in other areas of native vegetation. Its occurrence is changing the ecology of these areas by increasing the frequency and intensity of fire, which in turn is resulting in the conversion of native vegetation communities into savanna grasslands. The consequent elimination of trees, shrubs, and columnar cacti from these areas is a serious threat to the survival of the pygmy-owl, as those vegetation components are necessary for roosting, nesting, protection from predators, and thermal regulation.

Effects of buffelgrass pasture conversion on regional and global biogeochemical cycles and climate are widely recognized (Gash et al. 1996, Houghton et al. 1996). Encroachment of African grasses into native savanna, forest edges, and grasslands in many instances has altered fire regimes and produced significant changes in the flow of energy, nutrients, and water through these ecosystems. Direct effects of African grasses on ecosystem processes are likely to be subtle compared to disturbance and land clearing that often precedes their invasion. Nevertheless, African grasses may contribute directly to changes in ecosystem processes (Williams and Baruch 2000).

In Sonora, the Mexican government has subsidized the clearing of native vegetation and seeding of buffelgrass since the 1960s (Van Devender and Dimmit 2000) under the classification "range improvement", to increase livestock stocking rates. Approximately one-third of Sonora is suitable for conversion into buffelgrass (Ibarra et al. 1995). Conversions occur as a result of state and federal subsidies, which are matched by cattle owners at between 30 and 60 percent of the cost (as free bulldozer services, fuel, salaries, seed, etc (Burquez-Montijo et al. 2002).

The area already deliberately converted to buffelgrass in Sonora has been estimated at up to 1.6 million hectares (4 million acres) (about 10 percent of the state's area) (Burquez-Montijo et al. 2002), including approximately 2 million acres below 2,900 feet elevation (Yetman and Burquez 1994). Van Devender and Dimmit (2000) estimate that in central Sonora, more than 190,000 hectares (470,000 acres) have been cleared to plant buffelgrass. An additional 6 million hectares (1/3 of the state's area) has been targeted for conversion to buffelgrass (Navarro 1988; in

Williams and Baruch 2000). Extensive habitat conversions are also occurring in thornscrub and tropical deciduous forest communities. Buffelgrass plantations are now in abundance from Navajoa to Alamos, Sonora, where vast tracts of thornscrub and tropical deciduous forest have been cut by hand or smashed by bulldozers, and then replaced with what appears to be an African savannah (Bowden 1993).

There is some evidence that, after several years in buffelgrass production, soil nutrients become exhausted and buffelgrass begins to die. Ranchers that can afford to, burn the remaining plants, deep plow to bring nutrients to the surface, and then replant at great expense (Yetman and Burquez 1994). In some areas, native species, such as boat-thorn acacia (*Acacia cochliacantha*), Indian mallow (*Abutilon abutiloides*), and Sonoran bursage (*Ambrosia cordata*) are reclaiming some buffelgrass plantations (Van Devender and Dimmit 2000), which could represent early succession back to a native forest type, but buffelgrass is frequently burned intentionally, or wildfires occur, which destroy any young acacia or other native trees. Most plant species of thornscrub and tropical deciduous forest communities are not adapted to fire, whereas bufflegrass appears to thrive in a regime of frequent fire. In areas planted extensively with bufflegrass, Mexicans believe the climate is becoming hotter and drier. During drought, bufflegrass dies back and the soil erodes leaving vast areas of dust bowls in which neither people nor wildlife can prosper (Yetman and Burquez 1994).

In addition to conversion of native vegetation to buffelgrass plantations, buffelgrass is also invading extensive areas in both Mexico and the United States (Cox 1988; Ibarra et al, 1995), and it is considered fully naturalized in most of Sonora and southern Arizona, (Rutman and Dickson, 2000; Yetman and Burquez 1994). It is present in almost all of the Sonoran Desert, in a large portion of the Sonoran thornscrub, and in disturbed Sonoran and Sinaloan tropical deciduous forests (Burquez-Montijo et al. 2002). Burquez and Martinez-Yrizar (1997) determined that it has invaded more than two-thirds of Sonora, northen Sinaloa, some areas in the central peninsula of Baja California and southern Arizona. In southern Sonora, buffelgrass has been planted in clearings in tropical deciduous forest but apparently does not invade undisturbed shady forests; however, using fire management, buffelgrass can be maintained indefinitely (Van Devender and Dimmit 2000). Burquez-Montijo et al. (2002) state that "[b]uffelgrass is dispersing rapidly, naturalizing over an extensive area covering most of the continental Sonoran Desert and expanding into thornscrub and the peninsular Sonoran Desert." Buffelgrass is limited in its range when mean minimum temperatures in the coldest month are 41 degrees F or less (Cox 1988). Buffelgrass has been successfully established from seed at elevations from approximately 6 to 830 meters (20 to 2720 feet) above sea level and where annual precipitation ranges from 20 to 119 centimeters (8 to 47 inches) (Cox 1988). Buffelgrass in North America spreads where annual precipitation ranges from 33 to 55 centimeters (13 to 22 inches) (Ibarra et al, 1995).

In Arizona, bufflegrass is an increasingly apparent invasive weed of Sonoran Desert scrub or disturbed areas below 2,900 feet. In Pima County bufflegrass is one of the most invasive problematic plant species, where it grows in vacant lots, roadsides, and areas adjacent to roadsides from which the grass has invaded portions of Saguaro National Monument, Organ Pipe

Cactus National Monument, Tucson Mountain Park, the Tohono O'odham Nation, and lower elevations of the Coronado National Forest. Bufflegrass has not been planted in these areas, it is an invasive weed. A volunteer effort has been organized by the Arizona Sonora Desert Museum to eradicate bufflegrass from the Tucson Mountains. The effort has logged hundreds of volunteer hours. Organ Pipe Cactus National Monument also has an active eradication program.

Farther north in Maricopa County, bufflegrass is common along trails and in disturbed areas in city and county mountain parks in and near Phoenix. Along Interstate 8 in southwestern Arizona, we have documented bufflegrass as a common roadside weed from Gila Bend west to Dateland, and uncommonly as far west as Yuma. At Kofa National Wildlife Refuge in western Arizona, we have observed a colony of these plants at Big Eye Wash in the Castle Dome Mountains. In western Arizona, where annual precipitation is often less than 7 inches, buffelgrass is uncommon or localized as a roadside weed or in drainages, such as Big Eye Wash. However, drainages, which are most at risk in regard to bufflegrass invasion, support the most diverse plant and animal communities in the deserts of western Arizona.

Of particular concern is the introduction of fire into Sonoran Desert scrub communities invaded by buffelgrass. Sonoran Desert scrub is not adapted to fire; native grasses do not provide the fine fuels necessary to carry a fire. Recent introduction and spread of nonnative annual plants, such as cheatgrass (*Bromus* sp.), Mediterranean grass (*Schismus barbatus*), and Sahara mustard (*Brassica tournefortii*); as well as the perennial buffelgrass, increase fire frequency and intensity in desert scrub communities (Minnich 1994). When nonnative annual plants cure, or during dry periods when buffelgrass dries out, these nonnative plants can form continuous stands of fine fuels that carry fire. These fine fuels have resulted in increased fire frequency in desert scrub (Rogers and Steele 1980, Schmidt and Rogers 1988, Minnich 1994). Many desert trees, shrubs, and cacti, including saguaros, are poorly adapted to fire and cannot withstand buffelgrass fires; those that survive a fire generally still suffer severe damage and are eliminated in subsequent fires (Burquez-Montijo et al. 2002). Esque *et al.* (2000) reported mortality of adult saguaros in excess of 20 percent after a fire in desert scrub at Saguaro National Park. In areas where naturalized stands of buffelgrass are becoming dominant, natural fire cycles begin within a few years following colonization, which enlarges the affected area by eliminating the desert and thornscrub species and providing new seed sources (Burquez-Montijo et al. 2002). The introduction of buffelgrass into fire-intolerant subtropical and tropical communities results in a permanent conversion to a buffelgrass savanna with reduced plant cover and diversity (Van Devender and Dimmit 2000), containing stands of nonnative weeds and the relatively few native desert scrub species (e.g. *Encelia farinosa, Simmondsia californica,* and *Acacia greggii*) that are tolerant of fire. Once established, alien grasses, such as buffelgrass, suppress the regeneration of key desert species by setting in motion a grass/fire cycle by providing the fine fuel necessary to the initiation and propagation of fire (D'Antonio and Vitousek 1992). Alien grasses recover more rapidly than native species following such fires and cause a further increase in susceptibility to fire (D'Antonio and Vitousek 1992). Theoretically, if subsequent fires were prevented, it might take as long as twenty years for the total plant density to recover, and much longer for plant species composition to recover (Esque and Schwalbe 2002).

The conversion of native vegetation to buffelgrass savannas constitutes a serious threat to pygmy-owls by eliminating or suppressing regeneration of large columnar cacti in northern and central Sonora, especially in areas where saguaros are already uncommon (Flesch 2003). Buffelgrass areas have significantly lower species diversity and reduced structural complexity than the native desert scrub. Pygmy-owls were found in or adjacent to buffelgrass clearings that formed a mosaic of artificial savannah and native vegetation (Flesch 2003). However, these areas may be only temporary in nature, as fire intensity and frequency associated with buffelgrass continue to eliminate the native vegetation. The conversion of native vegetation to buffelgrass and the associated direct and indirect effects on habitat are an ongoing significant threat to pygmy-owls in Mexico (Flesch 2003). Survey data indicate that pygmy-owls are patchily distributed in Sonora, Mexico (Flesch 2003). Thus, impacts from habitat conversion can affect significant numbers of pygmy-owls even if the geographic area converted is not large.

Appendix 4. Literature Cited

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