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Conservation

Matthew J. Muir and Louise H. Emmons

ABSTRACT. Maned wolves (MW) (*Chrysocyon brachyurus*) are classified as "Near Threatened" on the International Union for Conservation of Nature (IUCN) Red List. Twenty-two subpopulations have been identified in Brazil, Argentina, Paraguay, Bolivia, and Peru, with an estimated 80%–90% of all MW occurring in Brazil. Only 5%–10% of maned wolf range is globally protected, but to understand how unprotected wolves are faring, better population surveys are needed on land outside of national parks and reserves. Although agricultural expansion is responsible for a contraction in the species' southern range, field studies consistently show that MW can survive in agricultural land with sufficient refugia and prey. Publicized threats include disease transmission by domestic dogs, road mortality, and hunting for folk medicine and in retaliation for livestock deaths. To these, we add fire and fire suppression, clear-cut pasture for livestock, and the emerging threat of climate change. Despite these ongoing threats, MW do not require intensive management to remain in a human-dominated landscape, and this resilience is the best hope for their successful conservation. Nonetheless, habitat management of grasslands could increase the population density of MW in protected areas.

INTRODUCTION

Through our research, we wanted to learn enough about maned wolves (MW) (*Chrysocyon brachyurus*) to suggest how their needs might be better met by conservation efforts in Bolivia. In the preceding chapters, we have presented field data and results on many aspects of the ecology of the MW on our study area: some findings are well known and many are new. These descriptive results pertain to individual animals in a specific place and time, and they can be generalized only by comparison with the results from other times and places. Compared to ecology, conservation is a different kind of subject, as we can bring to it no specific field results from regional management efforts. Rather, we can apply what we have observed to predict the status of future maned wolf populations. To include the variability and flexibility found across

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the species' range, we start with a range-wide overview of issues that can determine if a population will thrive or dwindle.

Within the Canidae, MW are exceptional not only in their ecology and evolutionary history (Chapter 1) but also in their conservation status. They are listed as "Near Threatened" by the International Union for Conservation of Nature (IUCN) (a threat category below "Vulnerable"; IUCN, 2009), but they have life history traits that predict high extinction risk for other carnivores, such as low reproductive capacity and occurrence at low density (Purvis et al., 2000; Chapter 4). Canids of similar size (>15 kg) in monotypic genera are classified as "Endangered" (African wild dog, *Lycaon pictus*; dhole, *Cuon alpinus*; IUCN Red List). Because MW do not kill ungulate livestock or wild species valued by human hunters, they have not been subjected to the campaigns of deliberate extermination that have brought other carnivores to extinction (Falkland Island wolf) or to its brink. Of no threat to people, they have stayed below the radar of both publicity and of conservation efforts. For example, in a review of maned wolf global status, Rodden et al. (2004) cited no conservation strategies for MW. This deficiency was remedied by a recent maned wolf conservation workshop in Brazil (Paula et al., 2008), which outlined status and threats in all range countries but primarily highlighted the vast information gaps to be filled. Relatively few conservation-related papers have been published on MW (15% of citations) compared to other large canids like the African wild dog (38%), dhole (20%), and Ethiopian wolf (46%, *Canis simensis*; Web of Science, keyword search, i.e., *Chrysocyon brachyurus*: subject category, Biodiversity and Conservation, June 2010).

This chapter is thus an assessment of what is known about maned wolf conservation and management, including where populations occur, what threatens these populations, and what conservation actions might mitigate those threats. Our focus is range-wide, but we will end with specific management recommendations for our study area in Noel Kempff Mercado National Park (NKP), drawing on findings from our 10 year field study (Chapters 2–6).

What Is Known and What More Needs To Be Known?

New literature on MW has grown exponentially since the 1960s, increasing by 50%–75% per decade (Figure 7.1). Starting with Reginald Pocock's (1927) notes on MW held at the London Zoo, we estimate that by 2010, 235 citations existed in English, German, Czech, Spanish, and Portuguese.

Information on maned wolf biology has accumulated unevenly. Excluding general reviews (N = 29), over half of all maned wolf citations originate from observations of captive individuals (N = 109). In the 1960s and 1970s, studies on captive MW outnumbered field observations by a factor of 5 (Figure 7.1). Since 1997, publications on free-ranging MW have steadily become more prevalent until they have equaled or exceeded literature on *ex situ* MW (excepting 2001). Of the 80 citations on free-ranging MW, 35% focus on diet (N = 28); 23% concern health and disease (N =18); 9% report ranging data (N = 7; home range, telemetry); and 6% deal with genetic analysis (N = 5). Literature highlighting MW as a conservation concern appeared as early as the 1960s (Carvahlo, 1968) and recent overviews include Rodden et al. (2004), Paula et al. (2008), and Pautasso (2009).

Planning for conservation action requires taking stock of what is known and what more needs to be known (Woodroffe et al., 2005). On the basis of current work, MW have the following requirements:

1. Diet: MW subsist primarily on fruit and small mammals (Chapter 4; Dietz, 1985) and consume most food items according to their availability (Rodrigues et al., 2007). We calculated the average daily energy needs of MW to be 1,580 kcal (Chapter 4). On the basis of the 50-50 prey-fruit diet generally reported for MW, this daily requirement can be met by two or three large rodents such as cavies (>250 g) and six to eight large, soft-pulped fruits such as *Solanum* spp. (Table 4.6, Chapter 4).
2. Space and habitat: maned wolf home ranges are from 25 to over 80 km^2 (Rodden et al., 2004; Jácomo et al., 2009; Chapter 3). Breeding pairs have little or no range overlap with other pairs (Dietz, 1985; Chapter 3) but can be associated with young adult females (Melo et al., 2007; Chapter 5). MW occur primarily in grassland and savanna and avoid areas where canopy cover exceeds 30% (Vynne, 2010). They can also be found in scrub forests, flooded habitats, livestock rangelands (Rodden et al., 2004), and cropland with refugia and prey (Vynne, 2010).
3. Population size and structure: Simulated populations of at least 50 MW were modeled to persist in the absence of harvest or habitat loss, while populations of over 250 MW were thought to be relatively robust to these threats (Paula et al., 2008).

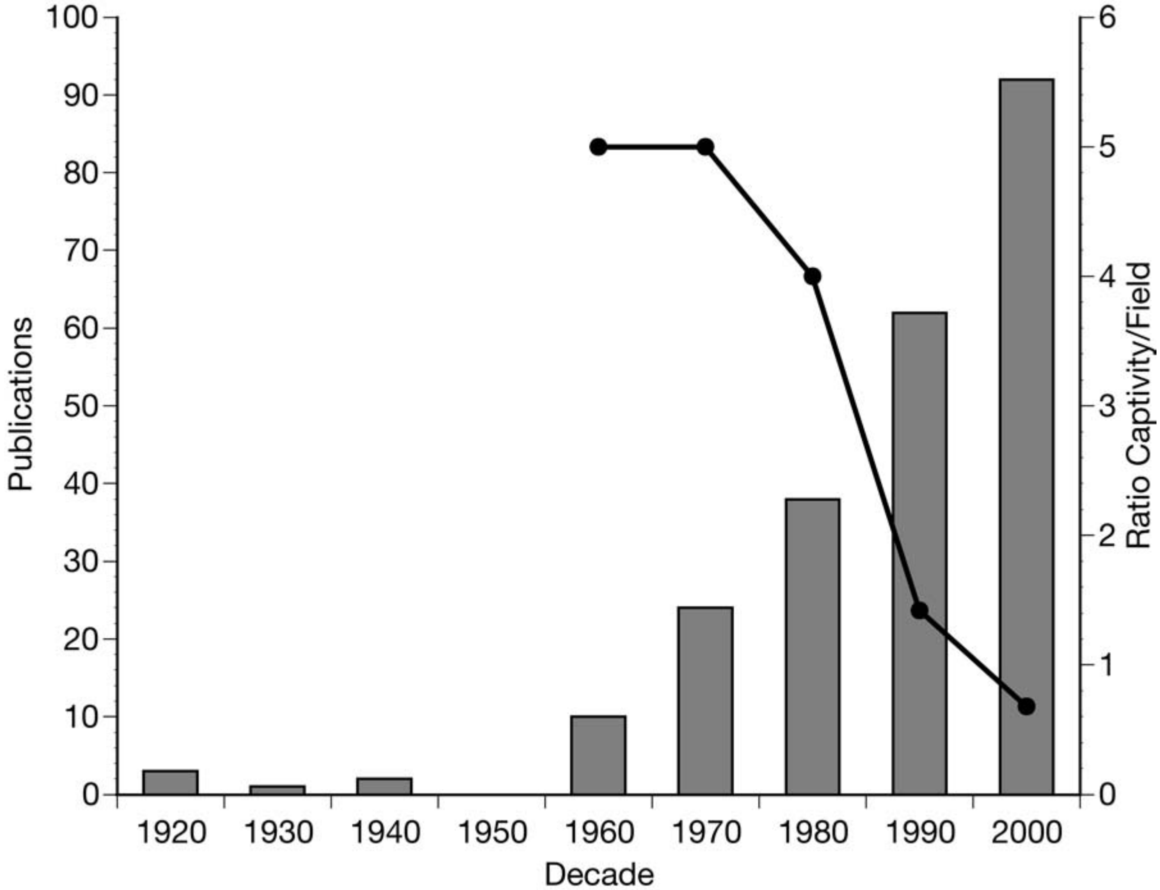

FIGURE 7.1. Publications on maned wolves (MW) by decade from 1927 to 2009. Secondary axis and point data show the ratio of publications on captive to field studies (Web of Science [keyword search = *Chrysocyon*] and personal libraries of L. H. Emmons and M. Rodden).

The persistence of MW populations is most sensitive to female mortality (Paula et al., 2008). No survivorship cost of inbreeding was found in captivity (Ralls et al., 1988).

4. Climate: Most areas in which MW occur receive 1,000–2,000 mm annual rainfall and the species' lower limit is likely between 600 and 1,000 mm (Quierolo et al., 2011). MW cease sustained activity when temperatures reach 30°C, probably to prevent water loss from panting, and in NKP they seemed to decrease travel below 20°C (Chapter 2).

Behavior (Dietz, 1984; Kleiman, 1972) and health (Bovee et al., 1981; Lamina and Brack, 1966) are relatively long- and well-studied aspects of maned wolf biology in captivity, but they are little known *in situ* (Chapters 5, 6). Information is scarce and scattered on the size and shape of populations, the scope and impact of threats, and the effectiveness of conservation strategies. Almost nothing is reported but anecdotal evidence on key life history parameters, such as litter size at birth, survivorship to weaning, or lifetime reproductive success of females.

Population and Geographic Distribution

The most definitive maned wolf distribution map is based on a collaborative effort that compiled all known point records of maned wolf occurrence (Queirolo et al., 2011). A 2005 population viability analysis (PVA) workshop held in Brazil identified maned wolf subpopulations in Brazil, Argentina, and Paraguay (Paula et al., 2008) with Bolivia and Peru evaluated later (R. C. Paula and

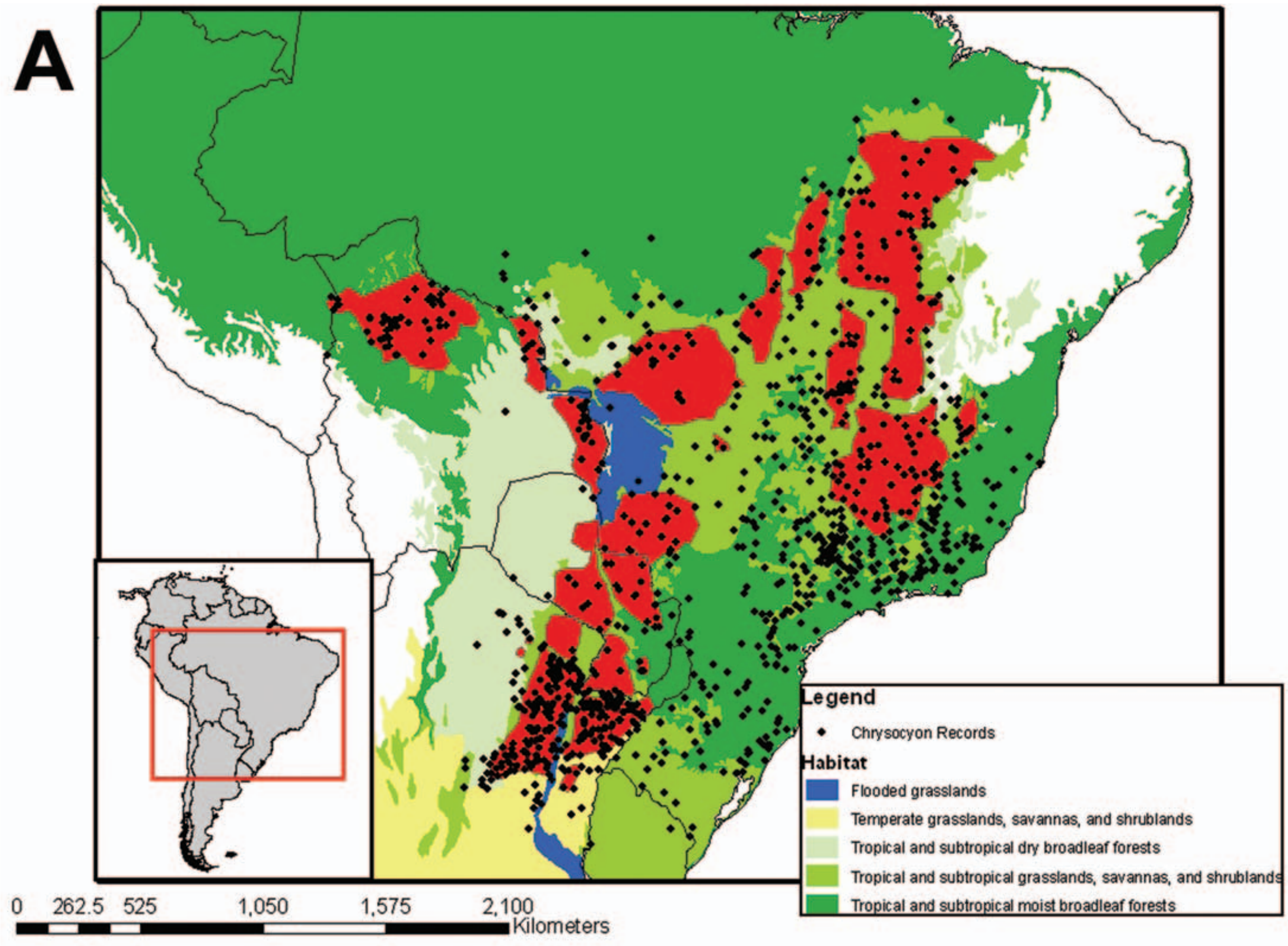

FIGURE 7.2. (A) Maned wolf distribution map and occurrence records. Point records from Queirolo et al. (2010) combined with 22 identified populations from Paula et al. (2008): red shading. Source for habitat coverage: WWF Terrestrial Ecoregions.

L. H. Emmons, unpublished). We here combine the two maps and hypothesize where discrete subpopulations still occur within the recent maned wolf distribution (Figure 7.2A, B). We emphasize that Figure 7.2B is hypothetical and that the existence and margins of subpopulations represented by polygons need both refining by local experts, and regular revision of maps, to track the collective understanding of where MW occur. Surveys of MW presence have included spoor identification, camera traps, informant interviews, and detection dogs (Vynne et al., 2011; Figure 7.3). Documenting absence is always problematic in conservation, and the maned wolf traits that increase detection probability (large-bodied, conspicuously colored, occasionally vocal) are countered by cryptic behavior (nocturnal, shy) and common names shared by other carnivore species (Queirolo et al., 2011).

Twenty-two subpopulations were identified in the 2005 workshop (Appendix A) and 1,126 occurrence records were collected by Queirolo et al. (2011). Approximately half of occurrence points fell within identified subpopulations (N = 586). Points falling outside of subpopulation polygons may represent transient individuals, an unidentified subpopulation or a more accurate margin of a nearby subpopulation, historical records from extirpated areas, or erroneous records of maned wolf presence. For example, subpopulations were not identified in the

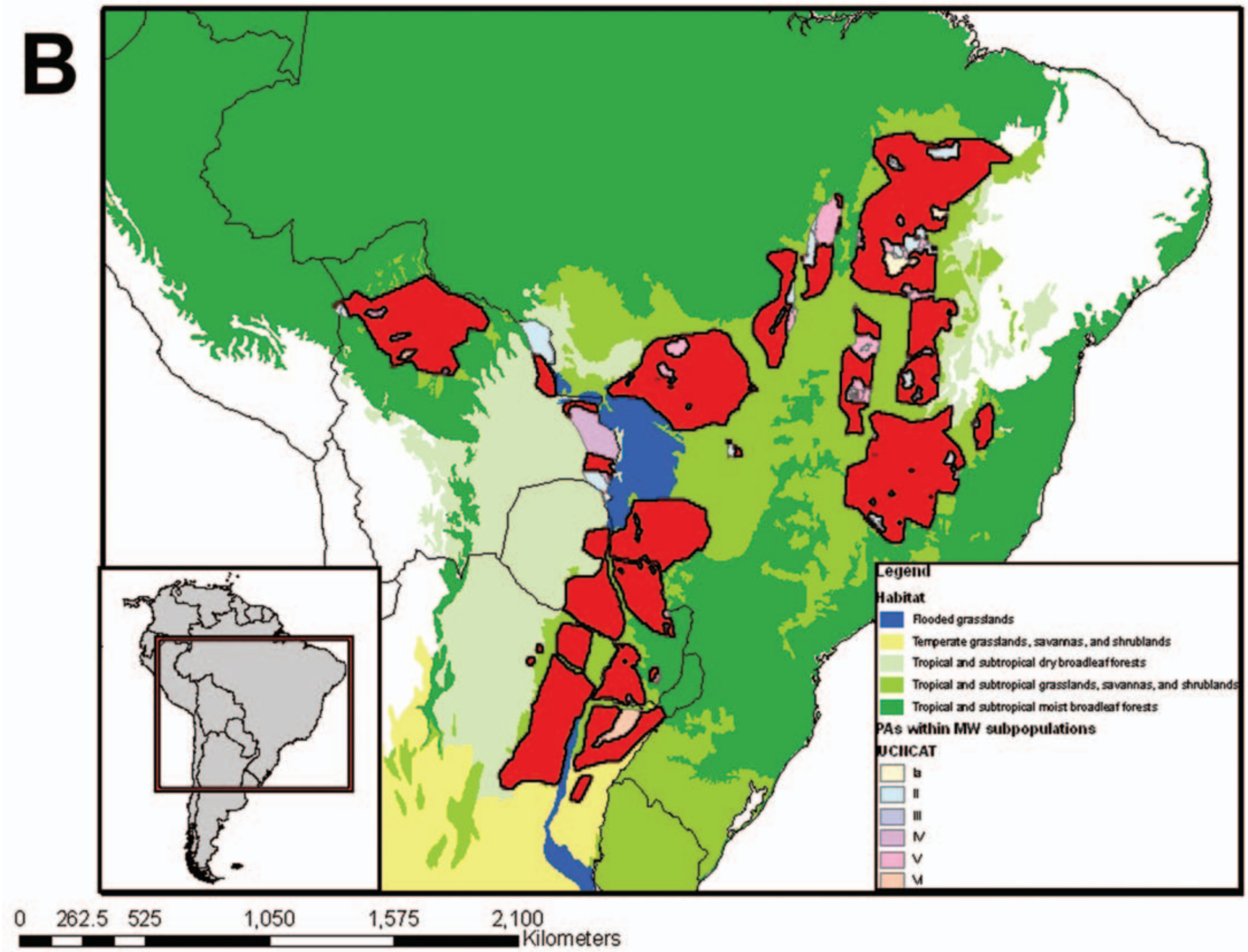

FIGURE 7.2. (B) Maned wolf distribution map and protected areas. Protected areas within populations from Paula et al. (2008): dark blue represents wetlands; red, subpopulations; paler shading, protected areas. Source for protected area coverage: World Database on Protected Areas (http://www.wdpa.org/ on 26 Jan 10). Source for habitat coverage: WWF Terrestrial Ecoregions.

Brazilian state of Sao Paulo or southern Brazil because workshop participants considered those populations “isolated and very small” (Paula et al., 2008). Thus the interstitial areas of Figure 7.2B may still contain resident MW. For example, there were no data available for a large area of potential habitat in the Beni savannas of Bolivia (Queirolo et al., 2011). See Appendix A for a description of each subpopulation and population estimate from Paula et al. (2008).

The available data suggest that more MW are found outside of formal conservation areas than within them. Only 5%–10% of occurrence records from Queirolo et al. (2011) are within a protected area (N = 54–117; range: IUCN Protected Area Categories Ia-IV to Ia-VI). Likewise, protected areas comprise only 7%–11% of the area included within identified subpopulations (Range: IUCN Ia-V to Ia-VI). Five subpopulations intersect no protected areas. If indigenous reserves are included, an additional 2% of both maned wolf records (N = 18) and area within subpopulations (34,000 km^2) are added.

There is no credible estimate of the global maned wolf population. Approximately 23,000 MW were counted

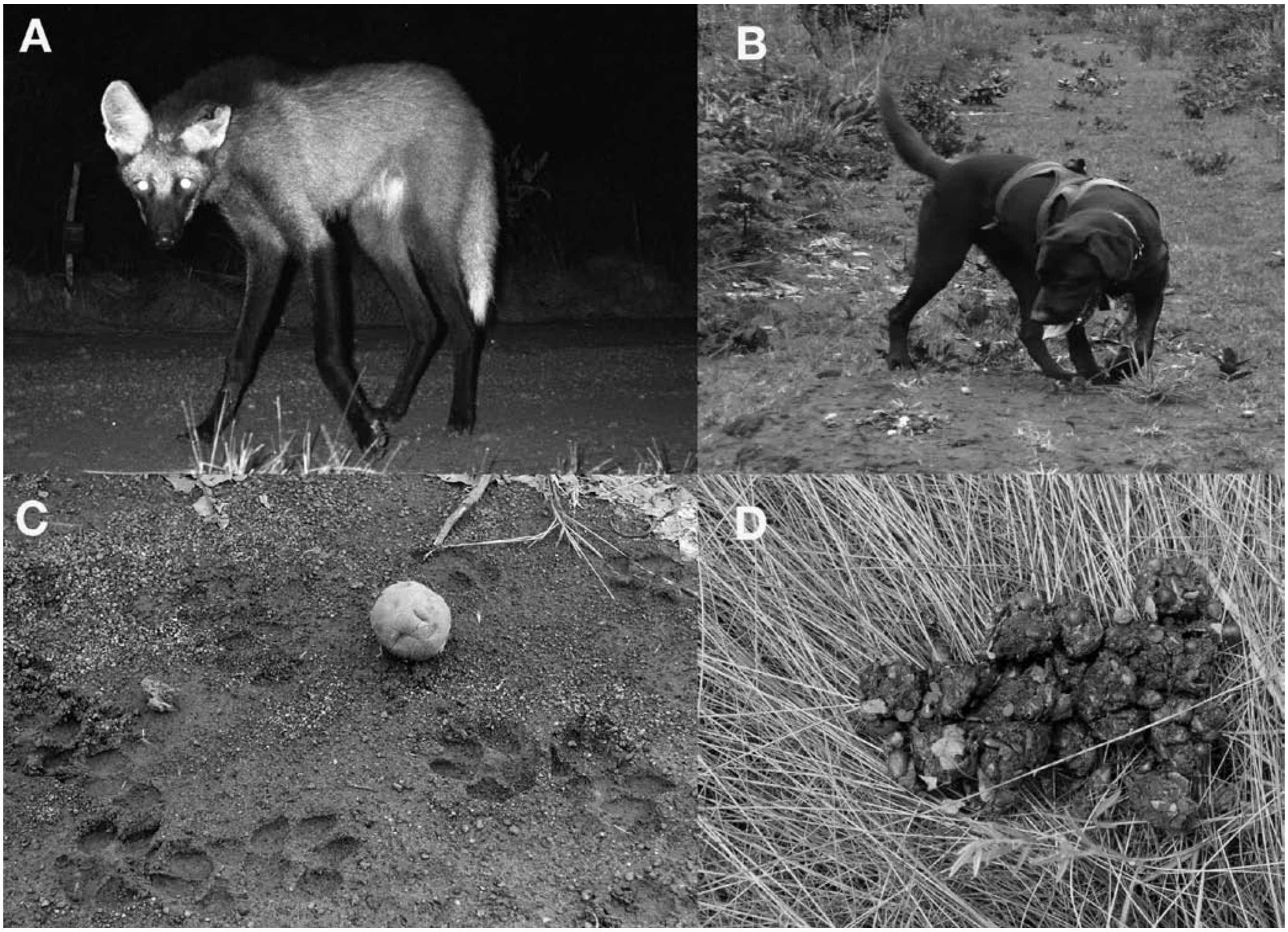

FIGURE 7.3. Methods to document maned wolf presence (top left, clockwise): (A) camera trap, unmarked individual with ear damage (NKP, photograph by M. Swarner), (B) scat-detection dog pointing at an old scat below right hind leg (Emas NP area; photograph by C. Vynne), (C) tracks and small (immature) *Solanum gomphodes* fruit with teeth marks, perhaps rejected as unripe (NKP, Bolivia; photograph by M. Swarner), (D) Scat with seeds of *Duguetia furfuracea, Solanum gomphodes, Emmotum nitens*, and other fruit, but no animal prey (NKP, photograph by L. Emmons).

in the summed efforts of the 2005 PVA workshop, with over 90% of them in Brazil (Paula et al., 2008: Brazil, *N* = 21,746; Argentina, *N* = 660; Paraguay, *N* = 830; Paula and L. H. Emmons, unpublished: Bolivia, *N* = 380). This estimate combined the best guesses of four national delegations and used extrapolations from density studies and informed speculation by local experts. For example, workshop participants from Brazil used a range of densities (2–10 individuals/100 km^2) to calculate a low and high estimate across the subpopulations there (Paula et al., 2008). Density estimates at individual sites, however, reach a maximum of 5.2 individuals/100 km^2 (Table 7.1). The range of published densities in Brazil (~1–5/100 km^2) suggests that the workshop estimates were overly optimistic. Using this published range instead, a revised population estimate for Brazilian MW is 11,820. Conversely, we now believe that the population in Bolivia was underestimated and that least 1,000 individuals may occur there. Combining these two revisions with the country estimates from Paula et al. (2008), we propose that approximately 14,700 MW occur in the wild.

Rodden et al. (2004) highlight the need for better population surveys. We suggest the following survey priorities: (1) censuses that distinguish breeding populations

TABLE 7.1. Densities reported for maned wolves (MW).

Density estimates (individuals /100 km²)	Habitat and country	Estimate method	Citation
3.6 ± 0.8	Cerrado farm, Brazil	Camera traps	Trolle et al., 2007
1.6 ± 0.8	Protected pantanal, Brazil	Camera traps	Trolle et al., 2007
5.2	Protected grassland, Brazil	Mark-recapture trapped MW	Silveira et al., 2009
4	Protected grassland, Bolivia	Longitudinal study of marked MW + camera traps	Emmons et al., this volume, Chapter 3

from transient individuals; (2) a refinement of the distribution maps by re-evaluating the subpopulations identified in the 2005 workshop with the data from Queirolo et al. (2011) and other newly reported maned wolf occurrences; and (3) more population surveys on agricultural land under different crop systems to understand the impact of human encroachment on maned wolf habitat suitability (Vynne, 2010).

Threats

By prioritizing identified threats, conservation action can be focused on the most relevant human actors. The IUCN Species Account for MW (Rodden et al., 2008) identifies four threats: habitat conversion to cropland, road mortality, domestic dogs, and hunting for folkloric medicine. Participants in the 2005 workshop identified habitat loss (including conversion to cropland and pasture) and harvest (including hunting, road kill, and shooting of "problem animals") as the two greatest threats to maned wolf populations (Paula et al., 2008). In Argentina, conflict with humans is also considered a serious threat (Soler et al., 2005).

In the following section, we consider these threats in Bolivia and propose two additional threats (fire and climate change). We focus on population-level threats but note that wherever MW live in small isolated populations, any combination of threats that increase mortality may have population consequences.

Conversion to Cropland

Savannas in maned wolf range are threatened by industrial-scale monocultures of soya, sunflower, sugar cane, maize, sorghum, rice, and others (Ratter et al., 1997). More than half of the Brazilian Cerrado has been cleared for agriculture (Klink and Machado, 2005), and it is being lost at a higher rate than is the Amazon forest (1.1% per year, Machado in Butler, 2009). As the most significant threat to MW (Rodden et al., 2008), agricultural expansion is thought to destroy habitat needed for reproduction and dispersal, as well as to increase the risk of other anthropogenic pressures (hunting for folkloric medicine, road mortality, disease transmission by domestic animals). Habitat loss has been greatest in southern Brazil, Argentina, and Uruguay (where MW may be represented only by transient individuals), and populations in those regions are restricted to remnant pockets of habitat "hemmed in on all sides by fields of soy, corn, sunflower, and wheat" (Queirolo et al., 2011).

Several studies suggest cautious optimism for maned wolf survival in farmland (Courtenay, 1994; Dietz, 1984; Lyra-Jorge et al., 2008; Santos et al., 2003; Vynne, 2010). Outside Emas NP, Brazil, Vynne (2010) found that MW can even survive in mechanized cropland where there is adequate land management, including at least 20% set aside on each farm as a wildlife refuge, and low-growing crops (soya) with sufficient rodent prey. It was not shown, however, whether the croplands were merely a sink for animals emigrating from the park. Quierolo et al. (2010) reported some recent expansion of the maned wolf geographic range into grazing land created by deforestation of humid Atlantic Forest (Mata Atlantica) of Brazil. In Bolivia, however, there is no evidence of MW expanding into or surviving in agroindustrial croplands. Sugar cane for biofuel production is now rapidly expanding in Brazil (Rudorff et al., 2010), ballooning from 2.57 million ha in 2003 to 4.45 million ha in 2008, and it now accounts for almost a quarter of all agricultural crops (Klink and Machado, 2005; Rudorff et al., 2010). Because of its height and lack of foraging opportunities, sugar cane is likely inhospitable to MW, and its expansion rapidly threatens to reverse any range gains for MW from deforestation (Vynne, 2010).

In Bolivia, monoculture crops overlap current maned wolf range only to a moderate extent and populations are primarily separated by forest. The greatest threat to connectivity is the extensively cleared land in Brazil that separates Bolivian MW from maned wolf populations in the Brazilian state of Mato Grosso. For example, the border between Bolivia and Brazil (and the edge of the protected area where our maned wolf fieldwork was conducted) is clearly defined in satellite imagery by intensive agriculture on the Brazilian side (Figure 7.4). The threat posed by modern crop production is likely to increase dramatically in Bolivia, especially if the proposed dams and inland waterway (Hidrovía) on the Rios Madeira-Guaporé-Paraguay lead to rapid agricultural growth and development in the adjacent Beni grasslands and Bolivian Pantanal. Recent expansion of industrial rice into Beni savannas is already directly replacing maned wolf historical habitat.

FIGURE 7.4. Satellite image of NKP, indicating much more intensive deforestation for agroindustry (palest polygons) in Brazil compared with Bolivia. Natural grasslands are darker pale areas, while the darkest zones are forest. Our Los Fierros (LF) study area, blackened by fire, is in the center of the image, and the Huanchaca Meseta is the curved structure to its NE–SE. The border of Brazil follows the edge of the agroindustrial deforestation, and new colonization in Bolivia can be seen approaching NKP on the lower left edge. Image by NASA-Terra FAS-Bolivia, October 2009.

Domestic Dogs

Domestic dogs can threaten maned wolf populations by food competition, aggression, and disease transmission (Rodden et al., 2008). In Bolivia, where feral domestic dogs are rare in maned wolf habitat, we consider only disease to be a plausible population threat. Depending on the pathogen and its local dynamics, diseases can be actively maintained by the domestic dog population (such as distemper) or persist as a legacy threat (such as canine heartworm) where the disease has been historically introduced by domestic dogs but can persist in their absence via reservoir species. In our study area in NKP, MW have been exposed to many disease agents spread by domestic dogs (Chapter 6; Table 7.2; Deem and Emmons, 2005; Fiorello et al., 2004), via either hunting dogs entering maned wolf habitat or perhaps by crab-eating zorros (*Cerdocyon thous*) moving between human and natural communities (Bronson et al., 2008). Pathogens now endemic to MW (canine adenovirus, giant kidney worm: *Dioctophyme renale*) may not always be shared by domestic dogs and are not normally considered a population threat.

Road Traffic

Maned wolf mortality due to vehicle traffic (i.e., road kill) is, unsurprisingly, greatest in areas where high-speed roads intersect or border maned wolf habitat. Fischer et al. (2003) note that MW are killed “more than rarely” on both Pantanal and Cerrado roads. While road traffic is considered a significant threat to maned wolf populations in Brazil and Argentina, the density and quality of Bolivian roads is lower. Thus, while individual MW do die on Bolivian roads, we suggest that the severity of this threat is relatively minor. As an additional mitigating factor, protected areas in Bolivia are not subdivided by high-speed roadways as they are some in other countries.

Hunting for Folkloric Medicine

MW are killed for numerous uses in traditional folk medicine: bronchitis, epilepsy, dizziness, kidney disease, back pain, love potions, protection against snakebite, and to bring good luck (Alves et al., 2010; L. H. Emmons, unpublished interviews). Because trade in maned wolf body parts is not on a large commercial scale (Rodden et

TABLE 7.2. Infectious and parasitic agents of domestic dogs to which MW show serologic exposure or that have been identified in the species.

Pathogen	Lethality	Transmission
Canine adenovirus	Can cause mortality in neonatal MW	Direct contact with body fluids or urine
Canine coronavirus	Not lethal; can cause mortality in conjunction with other pathogens	Oral-fecal contact with feces
Canine distemper virus	Can cause mortality in MW; linked to serious population declines in other canid species	Respiratory and contact with body fluids
Canine parvovirus	Can cause mortality in MW	Oral-fecal; virus can survive for months in environment
Rabies virus	Fatal to MW	Bite of rabid animal
Sarcoptes scabiei (causative agent of mange)	Susceptibility varies	Direct and indirect contact
Dirofilaria immitis (causative agent of heartworm disease)	Can cause mortality in MW	Mosquito-borne

al., 2008), medicinal harvest is not judged to be a major conservation concern for MW or indeed, any canid species (Alves et al., 2010). Our impression, however, is that hunting MW for folk medicine is greater in Bolivia than elsewhere and can be a substantial source of mortality in areas where maned wolf parts can bring high prices due to strong local beliefs in sorcery and folklore (M. Herrera, pers. comm.; Figure 7.5). For example, in San Matias, Bolivia, the meat of MW was purported to improve a person's ability to withstand chemotherapy for cancer, the pelt and bones to cure rheumatism and prevent osteoporosis, and pieces of skin to block malicious attempts of witchcraft (V. Sandoval, pers. comm.).

Retaliatory Killing for Livestock Damage

Killing of "problem animals" is an important source of maned wolf mortality in some areas (Paula et al., 2008). Over about a dozen years, Dietz (1984) recorded 21 maned wolf deaths caused by people; 16 of which occurred while MW were preying on chickens. Methods varied: "seven were shot, five were run down and killed by dogs, [and] four were trapped" (Dietz, 1984:27). Because maned wolf predation on poultry can be prevented with nighttime enclosures and predation does not extend to high-value livestock (cattle), human–MW conflict does not seem to be a severe threat to the species. MW are perceived to kill hoofed stock in some areas, but the lack of evidence in studies of diet suggests that hoofed stock predation is extremely rare or folkloric legend. In Bolivia, some cattlemen believe that MW kill calves to drink their blood, and in the Beni Department, a few ranch owners pay a bounty

FIGURE 7.5. One of two maned wolf skins found on an estancia in Bolivia. The wolf was killed for medicinal use of body parts. (Photograph by Vanessa Sandoval)

for killing MW as well as for jaguar and puma (M. Herrera, pers. comm.).

Fire and Fire Suppression

Fire and fire suppression are human activities that threaten maned wolf habitat (Klink and Machado, 2005). Outside of protected areas, farmers set annual fires for weed control and pasture maintenance that can inhibit the fruiting of woody plants for several years, depriving MW of fruit resources (Chapter 4; Sanaiotti and Magnusson, 1995). Inside protected areas, managers prevent and suppress fires, leading to the total loss of the grassland habitat through overgrowth by woody shrubs and trees that shade out grasses. These grass-free shrublands are depauperate of the rodents on which MW feed (Chapter 4; Emmons, unpublished) and fire suppression can lead to a vast accumulation of dry plant matter. The resulting buildup can fuel infrequent but exceptionally destructive fires (Silveira et al., 1999). In Emas NP, where protected area management resisted the controlled use of fire, catastrophic fires killed hundreds of large mammals and "a maned wolf *Chrysocyon brachyurus* was observed alight, running along a fire line towards a dead end" (p. 111, Silveira et al., 1999). A territorial maned wolf pair on our study area disappeared without trace after a fire burned the entire area in October 2009 (Chapter 6, Figure 1.10). We do not know when or how the pair died, but it was the only year that more than one collared adult resident was presumed to have died.

Although the balance between too much and too little fire is a site-specific function of the flora, climate, and soil, we believe that the appropriate fire frequency for maned wolf habitat is about every 3 to 4 years. Prior to European colonization, burn intervals ranged from three to 10 years and savanna fruit productivity requires at least three years to recover to pre-burn levels (Hoffman, 1998; Sanaiotti and Magnusson, 1995). Silveira et al. (1999) suggest that after three years, the accumulated fuel load creates a high risk of a catastrophic fire. Because recovery times vary between savanna shrub species, a spatial and temporal heterogeneity is required to maintain maximal populations of woody fruiting plants (such as *Solanum* spp., Anonnaceae spp., *Alibertia edulis*, and *Miconia albicans*). Our data also hint that fruit production may start to decrease the fourth year after fires (Table 4.5), which we attribute to increased loads of insect parasites on fruits, coupled with the waning of effects of ash fertilizers.

At our study site in NKP, we suspect that fire contributed directly to short-term cavy and armadillo declines in the NKP savanna at Los Fierros (Chapter 4), and indirectly, to long-term declines. Emmons hypothesized that dense atmospheric smoke from large, regional fires raises nocturnal temperatures and prevents dew formation, decreasing an important water source for savanna rodents and microbiota during months of drought (Emmons, 2009). Whether fire-related or perhaps related to some broader climatic shift, the volatility of the maned wolf food base has emerged from our studies in NKP as a potentially important threat to maned wolf fitness, but one perhaps amenable to management.

Climate Change

MW do not survive in hot and dry climates. The geographic range of MW skirts around Chaco habitat in western Paraguay and Bolivia, where annual precipitation is 550–1000 mm annually and temperatures can reach 40°C in the hottest month of January. Pautasso (2009) estimated that more than 10% of MW die in periods of extreme drought in Santa Fe, Argentina (2008, 615 mm), including deaths due to thirst-driven MW killed at drinking points for cattle and poisoned by drinking from the only surface water available, toxic canals.

In the next 70 years, temperatures are projected to increase across the maned wolf geographic range (Table 7.3; Intergovernmental Panel on Climate Change [IPCC], 2007). Comparing seven models, Boulanger et al. (2006) estimate that the region will warm by as much as 4°C by 2075–2100. In Chapter 2, we showed that maned wolf activity had a clear relationship with temperature, abruptly decreasing above 27°C–29°C and nearly ceasing above 30°C (Figure 2.2A). In a +4°C scenario, MW are

TABLE 7.3. Projected changes in temperature and precipitation in Amazonia, 2020–2080. Source: Intergovernmental Panel on Climate Change (2007).

Year	Season	Projected temperature change (°C)	Projected precipitation change (%)
2020	Dry season	+0.7 to +1.8	–10 to +4
	Wet season	+0.5 to +1.5	–3 to +6
2050	Dry season	+1.0 to +4.0	–20 to +10
	Wet season	+1.0 to +4.0	–5 to +10
2080	Dry season	+1.8 to +7.5	–40 to +10
	Wet season	+1.6 to +6.0	–10 to +10

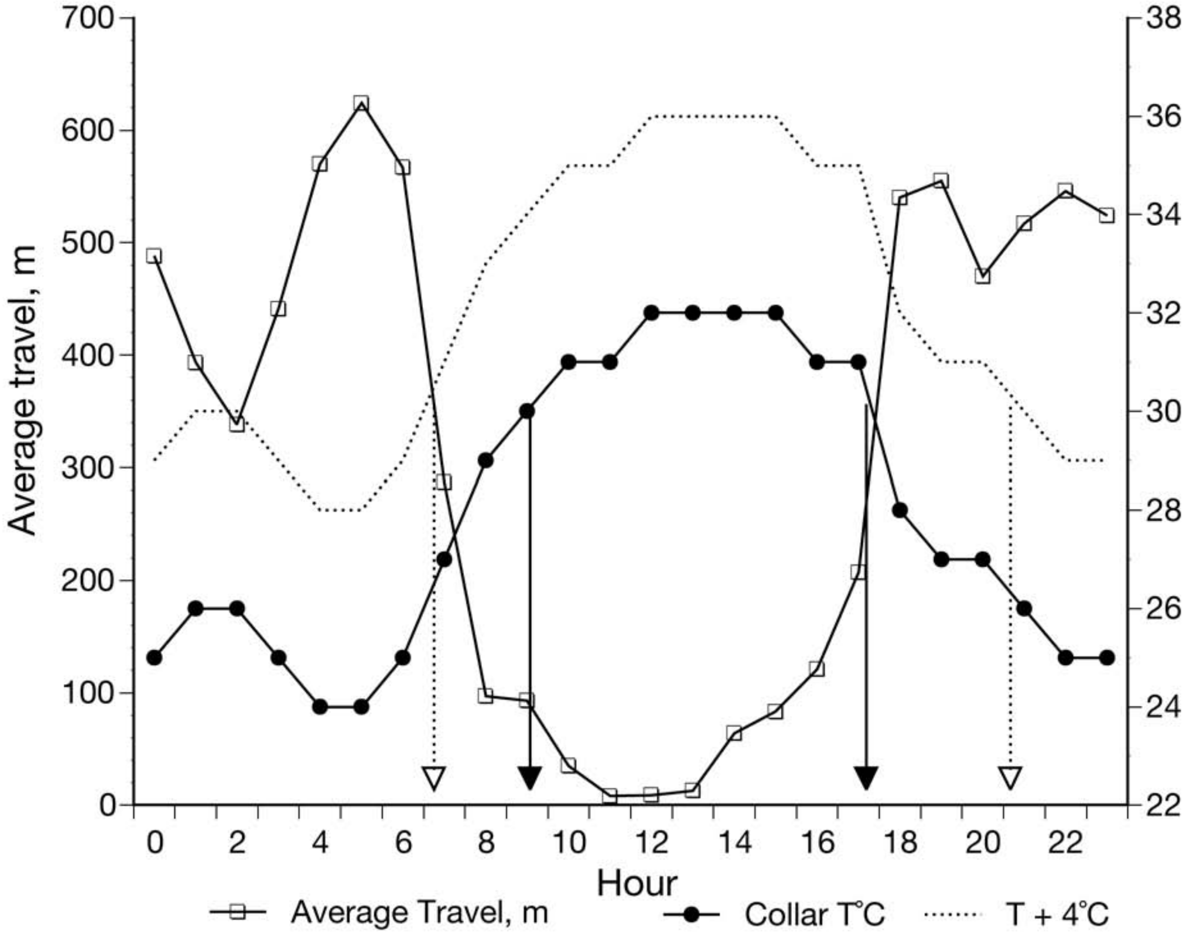

FIGURE 7.6. A modified Figure 2.2B (Chapter 2), illustrating a projected +4°C temperature change. Female maned wolf F3 2004–2005 average hourly travel (left axis, open squares) and average hourly collar temperature (right axis, closed circles); broken line is the collar T°C with 4°C added; vertical solid lines indicate the hour where the 2004–2005 collar temperature curve intersects 30°C (where travel nearly ceases); outer vertical dashed lines indicate where the same curve +4°C intersects 30°C. In the projected scenario, the temperature reaches at 30°C about 2.8 hours earlier in the morning (~0715) and goes below 30°C about 1.5 hours later in the evening (~2000), removing about 5 hours of peak travel time from the current maned wolf activity pattern.

projected to lose 5 hours of daily activity time (Figure 7.6). To compensate, all maned wolf behavior—foraging, social interactions, travel—would need to either become more efficient (i.e., accomplish the same amount in less time) or take place under heat stress that would require permanent proximity to water. In our study site at Los Fierros, the observed loss in body weight and reproductive failure of MW during a rodent decline is evidence that our study animals are living near their energetic limits. The stress of adapting to the new rhythms of a warmer climate is likely to push more marginal populations of MW to extinction.

Our +4°C adjustment (Figure 7.6) is an oversimplified representation of the complex climatic factors that will interact at a finer scale than the broad projections of the IPCC or Boulanger (2006). It also ignores all other environmental responses (vegetation change, reduction in rodent carrying capacity, water scarcity) to a 4° change in temperature. We believe, however, that our example illustrates the physiological limits that conservation biologists soon will be forced to consider, as well as the data that current behavioral ecology fieldwork can contribute to such scenarios. Precipitation and maned wolf water regulation will be even more difficult to predict and manage. The IPCC suggests that rainfall in the Amazonian region may increase or decrease from current levels. Given the great distances that MW traveled to seek water at NKP, we expect any decreases in precipitation to have at least as great, if not greater, an effect on maned wolf populations than would temperature increases alone.

Threats to Maned Wolf Habitat Integrity

As illustrated by the discussion of fire management, the health of maned wolf populations depends on the health and functionality of the ecosystems they inhabit. The major threats shared by species that co-occur with MW and are components of intact savanna ecosystems are also threats to MW, and the conservation of MW could likewise preserve those taxa.

To identify the species that share threats with MW, we used the search function of the IUCN Red List (Version 2009.2) and filtered species by country, habitat, and threat type. Of 1,080 terrestrial vertebrate species that share range countries and habitat types with MW, 4% are classified as Vulnerable (*N* = 46), 3% as Endangered (*N* = 29), and 1% as Critically Endangered (*N* = 15; IUCN Red List). Of the four threats identified for MW by Rodden et al. (2008), agriculture is the most widely shared threat, followed by hunting, roads, and nonnative species (Figure 7.7). While nonnative species likely refers to domestic dogs in the maned wolf species assessment, exotic grasses, introduced as pasture for cattle, are a major threat to Cerrado biodiversity and exacerbate the effects of other threats (fire: Klink and Machado, 2005).

Three other threats to savanna and grassland species are widespread (listed for more than 10% of IUCN-assessed species), but not identified in the IUCN maned wolf assessment (Rodden et al., 2008): fire or fire suppression, logging or wood harvesting, and livestock ranching. Maned wolves share fire as a threat, and its effect should be considered in conservation efforts across the species' range. In contrast, selective logging is unlikely to directly affect maned wolf populations. Wood harvest does not target the open vegetation or fruit species on which MW

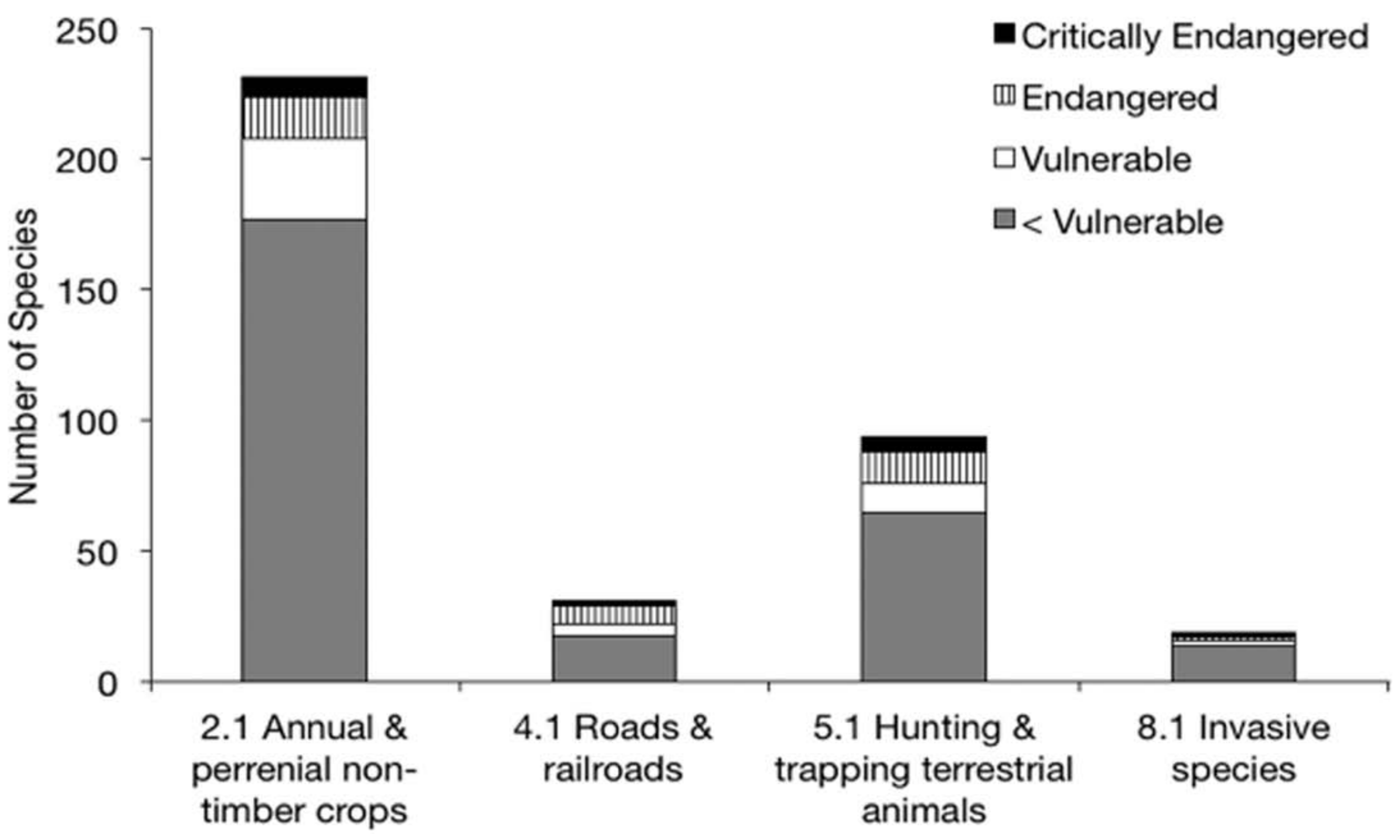

FIGURE 7.7. Number of savanna species that share IUCN threat categories (numbers) with MW by conservation status (IUCN Red List).

forage, so the fauna most likely to be affected are forest dwellers such as the monster rice rat (*Euryoryzomys lamia*) or tree nesters. Clear-cutting can increase available open habitat for MW (Quierolo et al., 2011).

Livestock ranching is likewise a mixed prospect for MW. Dietz (1984) found MW thriving on ranchland and Kawashima et al. (2007) suggested that MW may expand their range as forest is cut down for pasture, as has occurred in areas previously covered by Atlantic Forest (Queirolo et al., 2011; Santos et al., 2003). The lobeira fruit (*Solanum lypocarpum*) favored by MW can grow in abundance in rangelands and may even be facilitated by the disturbed areas associated with cattle ranching (Courtenay, 1994). Traditional cattle ranching on natural grasslands in Bolivia seems fully compatible with maned wolf survival, but conversely, "modern" ranching methods can destroy the plant and animal life on which MW depend. Pastures are bulldozed, burned, and seeded with invasive African grasses as forage (Klink and Machado, 2005). These grasses outcompete native vegetation and increase the intensity of fires, thus altering the system's succession and recovery. Vynne (2010) detected few MW in the surveyed cattle pastures of Goiás, Brazil. Because some pastures have little biomass to support rodent populations and few fruiting woody species (Santos et al., 2003, Vynne, 2010), artificial pasture may present lower food availability for MW than natural areas or even some cropland. As planted pasture has become the most widespread land use across the maned wolf range (40% of the Cerrado biome: Klink and Machado, 2005), we are only beginning to learn how maned wolf ecology and population trends are affected by rangeland conditions and how land use interacts with other threats, such as increased exposure to ectoparasites, diseases, pesticides, and stressors (May-Júnior et al., 2009).

Our web sample does not reflect threats to Data Deficient species on the IUCN Red List, including three species of the rodent genus *Juscelinomys*. Two are endemic to the grasslands of NPK, where MW eat them (Chapter 4). These are the only known surviving populations of their genus, as the other species (*J. candango*, from a now-destroyed Brazilian Cerrado site), has no known populations (Emmons, 1999). *Juscelinomys* spp. and other rare cerrado grassland rodents such as *Kunsia tomentosus* and *Kerodon acrobata* are threatened by any destruction of their habitats. The local extinction of *Cavia aperea*, the chief rodent prey of MW at Los Fierros, shows that even common and widespread rodents can be sensitive to apparently small environmental variations (Emmons, 2009), as Magnusson et al. (2010) also found for *Necromys lasiurus*.

Strategies To Reduce Threats to MW

Effective conservation action requires an understanding of the causal relationship between human activities and biodiversity threats. We constructed a conceptual model to diagram proximate and ultimate causes of maned wolf endangerment (Figure 7.8; Margoluis et al., 2009), based on the conservation issues known to affect MW and their habitat (Deem and Emmons, 2005; Dietz, 1984; Klink and Machado, 2005; Paula et al., 2008; Rodden et al., 2008).

More than describing how we understand the world to work, our conceptual model highlights which are the key threats and contributing factors where conservation efforts can intervene. We divide the effects of threats into those that directly affect MW (agriculture, domestic dogs, road traffic, and intentional mortality caused by people; Figure 7.8) and those that affect maned wolf grassland habitat (agriculture and fire management). Some contributing factors (maned wolf dispersal behavior, international demand for soya or biofuels) are unlikely to be influenced by a maned wolf conservation project and so would be unproductive as a focus for conservation efforts. Other factors, such as the perception that maned wolf body parts can cure sickness, can be mitigated by campaigns to change attitudes, values, and behaviors (Figure 7.9). Likewise, our veterinary team has worked to improve domestic dog health in the communities surrounding our maned wolf field site (Figure 7.10; Deem and Emmons, 2005; Bronson et al., 2009), as has been done by other maned wolf projects. Depending on the site and local capacity, programs can be developed to mitigate many causes of mortality (speed limits, incentives to provide legal frameworks to mitigate agricultural conversion).

Recommendations for Noel Kempff Mercado National Park

The conservation status of MW is tenuous within NKP. Because of the park's relative isolation and protected status, MW are unlikely to suffer some threats (road kill), but the small and fragmented populations are susceptible to unpredictable factors such as the 2004–2007 rodent decline, droughts, flooding, and fires (Chapters 4, 5; Emmons, 2009). We present recommendations by scale: (1) local management within the park and (2), regional or country-wide management. Both are vital to maintaining the ecological resilience of the park and healthy maned wolf populations, but while regional leadership must prepare for and address an external dynamic (Hidrovía

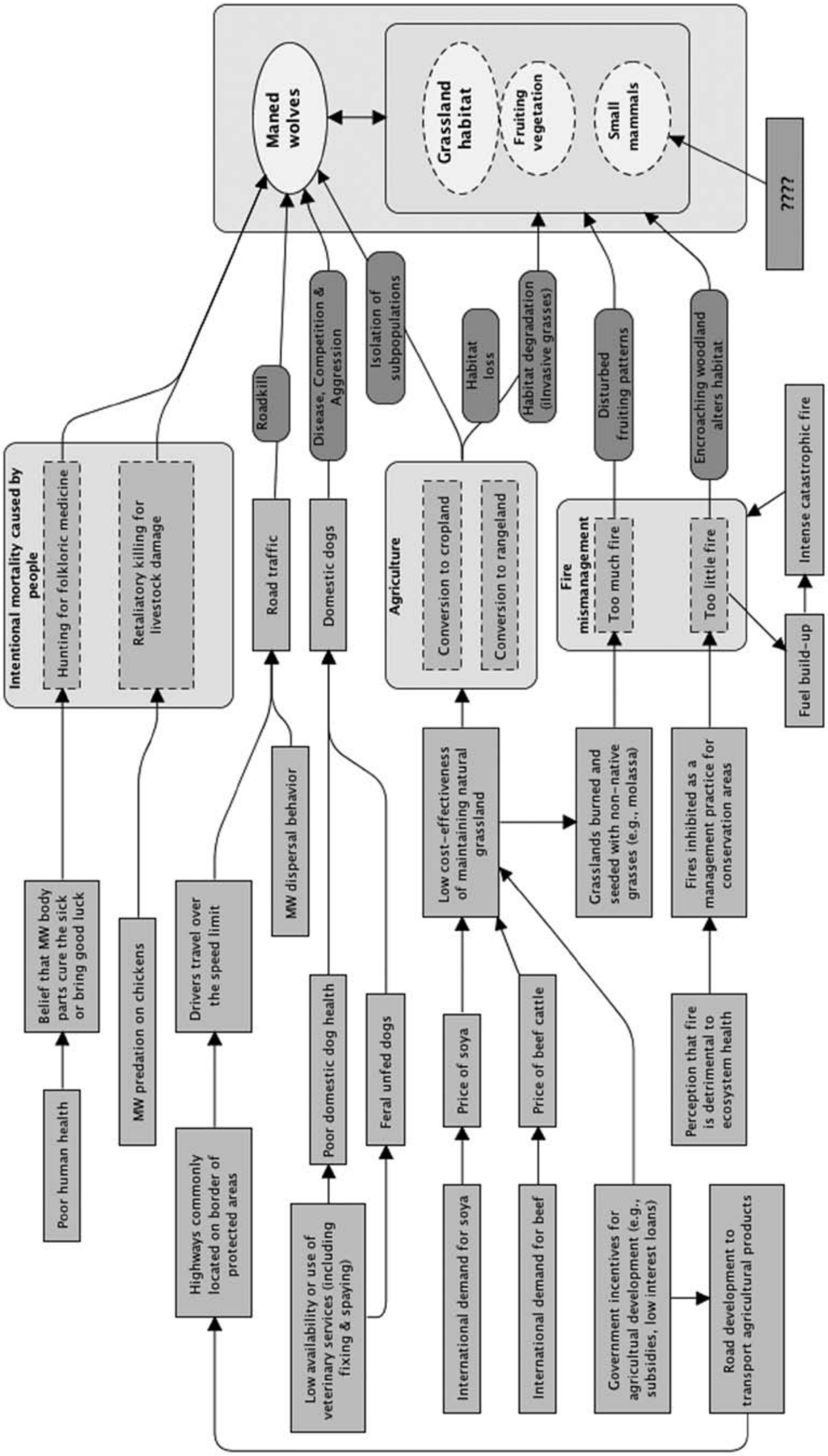

FIGURE 7.8. Conceptual model of the threats to maned wolf conservation and their contributing factors.

FIGURE 7.9. Public awareness poster about the ineffectiveness of animal parts as medicine, from Bolivia. The maned wolf in the lower right-hand corner is saying, “I’m not a pharmacy!” Color version of the poster is available at http://www.canids.org/species/Chrysocyon_brachyurus.htm. Artist: Alan Hesse.

FIGURE 7.10. Veterinarian Ellen Bronson monitoring domestic dog health in the community of Florida, outside NKP. Photograph by L. Emmons.

project and climate change), park management must tackle the on-the-ground direct threats to NKP MW (fire suppression and disease).

Local park management recommendations:

1. **Mitigate the effects of fire suppression and catastrophic fire by conducting yearly prescribed burns.** To maintain optimal habitat for MW, NKP lowland savannas will require burning with sufficient frequency to preserve the habitat as grassland, but in a spatial and temporal patchwork that maintains populations of woody fruiting plants (such as *Solanum* spp., Anonnaceae spp., *Alibertia edulis*, and *Miconia albicans*) in several stages of annual postfire regeneration on each maned wolf home range. In the flood-prone lowland savannas, prescribed burning in patches should occur on a 3–4 year rotation, and in months when conditions are not so dry that fires escape into nonprescribed areas. More urgently, overgrown savanna edges should be burned to restore the habitat's former extent. Existing roads can be cleared to act as fire breaks, as has been done in Emas NP, Brazil (Silveira et al., 1999). Savannas on the southern part of the Huanchaca Meseta burn regularly, perhaps too often, from fires started on fazendas in Brazil that propagate yearly across the tableland, but the northern part of the Meseta seems to be losing its grassland to overgrowth by shrubs.
2. **Suppress disease transmission between wildlife and domestic dogs and cats by excluding domestic animals from the park and vaccinating those on the periphery.** Exposure to a number of pathogens was found at high prevalence in domestic dogs near the park, but not simultaneously in the NKP maned wolf population (canine distemper and rabies; Bronson et al., 2008; Chapter 6). This encouraging result suggests that domestic dogs are not directly

exposing MW to disease. Maintaining this separation is extremely important and to continue to do so, we recommend two universal rules: "1) prohibit the release of individuals of wild species from captivity into wild populations, unless the wild populations are threatened and in need of augmentation for survival, and strict health and genetic evaluations have been performed before release; and 2) exclude all pets and other domestic animals from parks" (Deem and Emmons, 2005:196). While perhaps not by direct transmission from dogs, MW in NKP have been exposed to a number of potentially lethal diseases that are transmitted by domestic dogs and cats. We recommend regular rabies vaccination of local pets and livestock and distemper vaccination of dogs. Both diseases have effective vaccines and recur in multiyear cycles when new generations of susceptible animals are at sufficient density. Healthier pets also mean healthier children.

Regional-scale recommendations:

1. **Seek partnerships with adjacent ranchers to resist and mitigate the effects of agroindustrial development.** The proposed Hidrovía inland waterway and consequent traffic on the park border would be disastrous to maned wolf populations. Adjacent ranches, now in seminatural grassland, would likely be converted into agroindustry and isolate MW in the park. Buffers should be sought to maintain adjacent land in seminatural pasture with appropriate land management, including at least 20% set aside on each farm as an undeveloped refuge for wildlife (as per Brazilian land use laws). Partnerships should also be established with ranchers between the park and adjacent villages (e.g., Campamento) to create seminatural cerrado habitat for maned wolf subsistence and dispersal.
2. **Prepare for climate change by increasing connectivity to other grasslands.** The type of peripheral land connectivity described above is also thought to be one of the best strategies for protected areas to prepare for climate change (Hannah, 2008). Early interventions can be both more effective and less costly than delayed or no action (Hannah et al., 2008). If climate changes render some fragments of savanna unsuitable for MW (lack of dry season water), park managers should consider support for more intensive management interventions, such as maintaining water holes at several points in August–October.

CONCLUSION

Enabled by the technology of GPS telemetry, we are now in a golden age of maned wolf study. Insight into their ecology and daily lives is growing sharper and a growing cohort of researchers contributes information about wild maned wolf populations. We are also more acutely aware of the human activities that threaten them. The species as a whole is endangered by unmitigated agroindustry. Where populations are small and isolated, a number of threats and management actions have been identified for conservationists and park managers. The next challenge is to link maned wolf conservation to the emerging threats of climate change, invasive grasses, and biofuel production. Long-term field studies have never been more important, but funders want quick results. Only longitudinal research supplies the baseline for detection of emerging problems and helps identify environmental change early enough to pose research questions and eventually help mitigate them (rodent declines: Emmons, 2009; biofuels: Vynne, 2010; climate change: Chapter 2).

As understanding of maned wolf ecology grows, so, too, does the evidence that MW are resilient for a large canid. Dietz (1984) reported that although MW were highly sensitive to the physical presence of people, they were tolerant of agriculture and persisted where ranchers and farmers had earned a livelihood for generations. Vynne (2010) has found MW in soya fields, Lyra-Jorge et al. (2008) documented their presence in eucalyptus plantations, and Santos et al. (2003) showed them to thrive on dairy farms cut from Atlantic forest. If sufficient resources are available, MW do not need intensive management. Long-distance dispersal is crucial to the conservation success of species in fragmented landscapes (Trakhtenbrot et al., 2005) and fortunately, MW are far travelers. In rare events, they have been recorded crossing hundreds, even thousands, of kilometers of unsuitable habitat (Queirolo et al., 2011). Models, imperfect as they are, suggest that maned wolf populations have the potential to grow quickly (Paula et al., 2008) and that some populations are expected to persist for hundreds of years, even under worst-case scenarios (high inbreeding, high rates of habitat loss, and high population variability; Rodrigues and Diniz-Filho, 2007). Nonetheless, we should not diminish the evidence that in the past hundred years, MW have lost extensive habitat and geographic range, and the status of many subpopulations is desperate. However, it is also clear that if enough prey and fruit can be kept in the landscape, MW can live beside us for a long time to come.

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APPENDIX A: MANED WOLF SUBPOPULATIONS

In October 2005, a PVA workshop was held in Serra da Canastra National Park, Brazil (Paula et al., 2008). National delegations identified 19 maned wolf subpopulations in Brazil, Argentina, and Paraguay. Bolivia and Peru were considered later (R. C. Paula and L. H. Emmons, unpublished) with three additional subpopulations being recognized. Here, we compile workshop results into one map (Figure 7.11). Each identified maned wolf subpopulation, or landscape, is represented as a numbered polygon. We know the map is incomplete. For example, subpopulations were not identified in the Brazilian state of São Paulo or southern Brazil because workshop participants considered

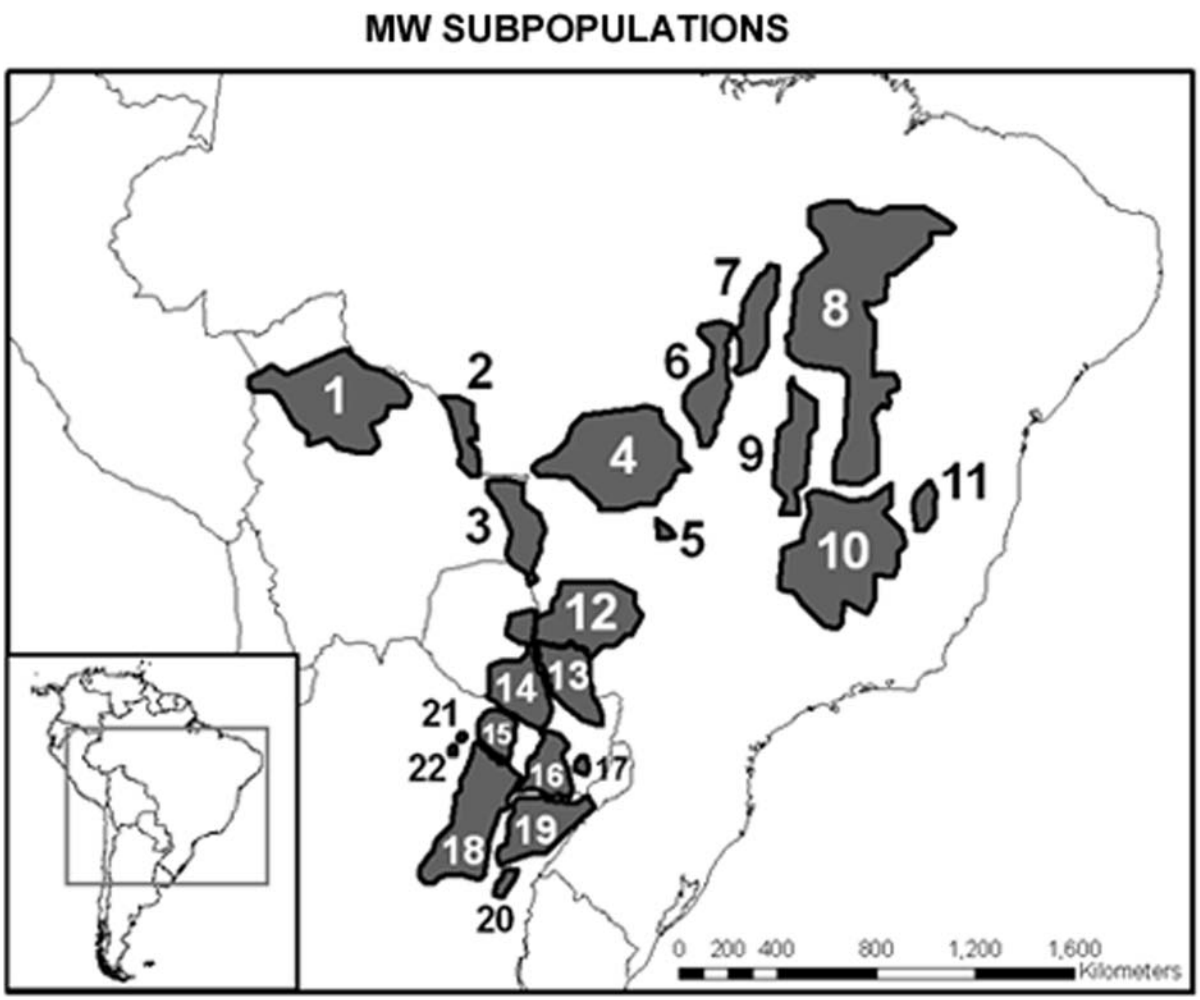

FIGURE 7.11. Twenty-two identified subpopulations (or landscapes) for MW. Source: Paula et al. (2008) and Quierolo et al. (2011).

those populations "isolated and very small" (Paula et al., 2008). We have also introduced a source of error by manually drawing the polygons in ArcGIS 9.1, based on the figures in Paula et al. (2008) and political and natural boundaries.

We tabulate the basic details of each subpopulation, including protected areas and population estimates given by Paula et al. (2008; Table 7.4). Workshop participants estimated that 23,631 MW exist in the wild. On the basis of the published range of maned wolf densities and our own upwardly revised estimate of MW in Bolivia, we propose that the number is likely closer to 15,000. The total estimated area of the 22 landscapes is approximately 1.5 million km^2. Within that, approximately 200,000 km^2 is included within a protected area under the most inclusive definition: all IUCN categories, plus uncategorized. The IUCN Protected Areas I–IV compose 102,000 km^2, IUCN Protected Areas V–VI contribute 63,000 km^2, and all others, 34,000 km^2. These are likely maximum estimates of protected coverage for MW because not all protected areas in the subpopulation margins likely support MW, and much of the habitat within them is not suitable (e.g., only a third of NKP is savanna).

We reemphasize that Figure 7.11 is hypothetical and that the existence and margins of subpopulations need verification by local experts. New data have already improved upon this map; for example, in Landscape 18, the distribution of MW has been refined into two areas of high density, one in Santa Fe Province, the other straddling the border of Córdoba and Santiago del Estero Province, and a larger, less dense zone of occupation that is fully joined with Landscapes 19 and 20 (Pautasso, 2009: fig. 9). Queirolo et al. (2010) also present more detail on connectivity and presence in individual states and provinces. For consistency we did not revise any subpopulations from the 2005 contributions. Revising the global distribution of MW is a continual necessity, and also a Herculean task that is best tackled by the community of all those interested in the status and future of MW. A campaign for mammals on the model of the Christmas Bird Counts in the United States, perhaps with the participation of schools, or a web tool like iNaturalist.org might yield better data on current distribution trends.

TABLE 7.4. Twenty-two identified subpopulations of MW in Brazil, Argentina, Paraguay, Bolivia, and Peru. Source: Paula et al. (2008).

Landscape No.	Description	Representative Protected Areas (PAs)	Population estimate	Total Area	PA I–IV	PA V–VI	Other PAs	Total PAs
1	Bolivia and Peru. Includes populations in the grasslands of the Beni Department, Bolivia, and the tiny population in the Pampas del Heath National Sanctuary, Peru. Some exchange is expected with Noel Kempff Mercado population (2).	Estación Biológica del Beni (Biosphere Reserve, IUCN VI); Estancias San Rafael (Wildlife Refuge, IUCN IV); Estancias Elsner Espírir (Wildlife Refuge, IUCN IV); El Dorado (Wildlife Refuge, IUCN IV); Madidi National Park (IUCN II); Bahuaja Sonéné National Park (Peru, IUCN II).	130	150,343	5,259	1,440	3,130	9,829
2	Bolivia. Includes the populations in and around Noel Kempff Mercado National Park, Santa Cruz Department. Some exchange is expected with the Beni (1) and San Matías (3) populations.	Noel Kempff Mercado National Park (IUCN II).	180	25,229	14,377	0	0	14,377

(*continued*)

TABLE 7.4. *Continued*

Landscape No.	Description	Representative Protected Areas (PAs)	Population estimate	Total Area	PA I–IV	PA V–VI	Other PAs	Total PAs
3	Bolivia. Includes the populations in the Pantanal and in the two large protected areas (Otuquis National Park in the south and San Matías in the north) and associated reserves, Santa Cruz Department. Some exchange is expected with the Noel Kempff Mercado (2) and potentially with the Mato Grosso do Sul (12) and West Paraguay (14) populations.	San Matías Integrated Management Natural Area (IUCN IV); Otuquis National Park (IUCN II).	70	33,886	33,886	0	0	33,886
4	Brazil. Includes the populations in the cerrado of central and southern Mato Grosso State. Some exchange is expected with the Emas (5) and eastern Mato Grosso (6) populations.	Cabeceiras do Rio Cuiabá (State Environmental Protection Area, IUCN V); Chapada dos Guimarães (State Environmental Protection Area, IUCN V); Serra das Araras (State park, IUCN II); Dom Osório Stoffel (State Park, IUCN II); Serra Azul (State Park, IUCN II); Gruta da Lagoa Azul (State Park, IUCN II); several indigenous reserves (the largest: Parabubure Indigenous Area).	1,764	165,450	990	6,804	8,444	16,237
5	Brazil. Includes the cerrado populations in and around Emas National Park, southern Goiás State. Some exchange is expected with the southern Mato Grosso (4) and Mato Grosso do Sul (12) populations.	Emas National Park (IUCN II), associated buffer PAs around Emas National Park.	127	3,374	1,283		1,088	2,371
6	Brazil. Includes the populations in the cerrado of eastern Mato Grosso, which includes several indigenous reserves. Some exchange is expected with southern Mato Grosso (4) populations and potentially with the western Tocantins (7) population.	Rio das Mortes (State Wildlife Refuge, IUCN III); Meandros do Rio Araguaia (Environmental Protection Area, IUCN V); indigenous reserves with MW records: Pimentel Barbosa Indigenous Area, Areões Indigenous Area.	1,412	51,952	3,312	2,496	5,256	11,064

(*continued*)

TABLE 7.4. *Continued*

Land-scape No.	Description	Representative Protected Areas (PAs)	Population estimate	Total Area	PA I–IV	PA V–VI	Other PAs	Total PAs
7	Brazil. Includes the populations in and around the cerrado and flooded grasslands of Bananal Island, the largest fluvial island in the world, western Tocantins State. Potential exchange is expected with eastern Mato Grosso (6) and Piauí and Maranhão (8) populations.	Araguaia National Park (IUCN II); also indigenous area, large adjacent to south of National Park: Parque do Araguaia Indigenous Area.	1,625	41,927	5,402	14,954	4,302	24,658
8	Brazil. Includes populations in the Cerrado of Piauí, Bahia, Maranhão, and eastern Tocantins States. Some exchange is expected with the Goiás (9) and central Minas Gerais (10) populations.	Mirador (State Park, IUCN II); Chapada das Mesas National Park (IUCN II); Uruçui-Una Ecological Station (IUCN Ia); Nascentes do Rio Parnaiba National Park (IUCN II); Cabeceira do Rio das Balsas, (State Environmental Protection Area, IUCN V); Serra Geral do Tocantins (IUCN Ia); Jalapão (State Park, IUCN II, and State Environmental Protection Area, IUCN V); Serra da Tabatinga (Environmental Protection Area, IUCN V); Bacia do Rio Janeiro (State Environmental Protection Area, IUCN V); Serra do Lajeado (State Environmental Protection Area, IUCN V); Cristópolis National Forest (IUCN VI); Veredas do Oeste Baiano (Wildlife Refuge, IUCN III); Grande Sertão Veredas (IUCN II); Veredas do Acari (State Park, IUCN II); Cavernas do Peruaçu (Environmental Protection Area, IUCN V); several indigenous areas, including Kraolandia Indigenous Area.	10,384	327,751	30,024	9,207	6,440	45,672

(*continued*)

TABLE 7.4. *Continued*

Land-scape No.	Description	Representative Protected Areas (PAs)	Population estimate	Total Area	PA I–IV	PA V–VI	Other PAs	Total PAs
9	Brazil. Includes populations in the cerrado of Goiás. Some exchange is expected with the Bahia (8) and central Minas Gerais (10) populations.	Chapada dos Veadeiros National Park (IUCN II); buffer: Pouso Alto (State Environmental Protection Area (IUCN V); Planalto Central (Environmental Protection Area, IUCN V); Bacia do Rio São Bartolomeu (Environmental Protection Area, IUCN V); several other EPAs in this Planalto complex.	2,173	55,551	1,334	14,077	0	15,412
10	Brazil. Includes populations in the cerrado of central Minas Gerais. Many MW records from Queirolo et al. (2011) were identified to the south of this landscape, suggesting that its margins may be larger or that distinct subpopulations exist in southern Minas Gerais and São Paulo States. Some exchange is expected with the Bahia (8), Goiás (9), and northeastern Minas Gerais (11) populations.	Serra da Canastra National Park (IUCN II); Córrego Feio e Fundo e Areia (State Area of Special Protection, IUCN V); Confusão (State Area of Special Protection, IUCN V); Sempre-Vivas National Park (IUCN II); Biribiri State Park (IUCN II); Águas Vertentes (State Environmental Protection Area (IUCN V).	3,091	186,264	3,501	1,165	0	4,666
11	Brazil. Includes populations in the Cerrado of northeastern Minas Gerais. Some exchange is expected with the central Minas Gerais (10) populations.	Grão-Mogol State Park (IUCN II); Acauã State Ecological Station (IUCN Ia).	386	13,336	409	0	0	409
12	Brazil. Includes populations in the Pantanal and cerrrado of Mato Grosso do Sul. Some exchange is expected with the Emas (5) and potentially with eastern (13) and western (14) Paraguay.	Serra da Bodoquena National Park (IUCN II); Kadiwéu Indigenous Area; Cachoeirinha Indigenous Area; Taunay/Ipegue Indigenous Area; Buriti Indigenous Area; Nioaque Indigenous Area; Jatayvari Indigenous Area; Ñande Ru Marangatu Indigenous Area; Pirakua Indigenous Area; Dourados Indigenous Area; Panambizinho Indigenous Area	784	92,422	772	0	3,204	3,975

(*continued*)

TABLE 7.4. *Continued*

Land-scape No.	Description	Representative Protected Areas (PAs)	Population estimate	Total Area	PA I–IV	PA V–VI	Other PAs	Total PAs
13	Paraguay. Includes populations in 12–20 cerrado and subtropical grassland areas scattered in eastern Paraguay. Potential exchange with Mato Grosso do Sul (12) and western Paraguay (14) populations.	Morombi Private Reserve (IUCN IV); Natural Reserve de Bosque Mbaracayú Private Reserve (IUCN V); Cerro Corá National Park (IUCN II); Arroyo Blanco Private Reserve (IUCN IV); Bella Vista National Park (IUCN II); San Luis National Park (IUCN II); Paso Bravo National Park (proposed).	150	50,674	653	545	993	2,191
14	Paraguay. Includes populations in the Pantanal and subtropical savanna in western Paraguay. Very little protected area coverage, but contains relatively low human density. Potential exchange with Mato Grosso do Sul (12), eastern Paraguay (13), and southern Paraguay (16).	Río Pilcomayo (IUCN II).	500	65,378	9	0	74	82
15	Argentina. Includes populations in the subtropical grasslands of Formosa Province. Few MW records from Queirolo et al. (2011) were identified within this landscape. Exchange is expected with Santiago del Estero (18) populations.	No protected areas identified.	100	22,671	0	0	0	0
16	Paraguay. Includes populations in the subtropical grasslands and wetlands of southern Paraguay. Exchange is expected with San Rafael (17) populations and potentially with western Paraguay (14), Corrientes Province (19), and Santa Fe Province (18) populations.	Yabebyry Wilderness Area (IUCN IV); Ybycuí National Park (IUCN II); Macizo Acahay National Monument (IUCN III); Ypacaraí National Park (IUCN II).	150	35,472	554	3	1,225	1,781

(*continued*)

TABLE 7.4. *Continued*

Landscape No.	Description	Representative Protected Areas (PAs)	Population estimate	Total Area	PA I–IV	PA V–VI	Other PAs	Total PAs
17	Paraguay. Includes a small population in and around the subtropical savannas of San Rafael NP. Exchange is expected with southern Paraguay (16) populations.	San Rafael Managed Resource Reserve (IUCN VI); Caaguazú National Park (IUCN II).	30	2,990	50	624	0	674
18	Argentina. Includes populations in the subtropical grasslands of Santa Fe, Córdoba, and Santiago del Estero provinces. Some exchange is expected with Formasa Province (15) and Chaquito (21) populations and potentially with southern Paraguay (16) and Corrientes (19) and Entre Ríos (20) province populations.	Chiquita Nature Reserve, (IUCN VI).	230	106,492	0	42	0	42
19	Argentina. Includes populations in the subtropical savannas and wetlands of Corrientes and Misiones provinces. Several MW records in Queirolo et al. (2011) were identified to the east of this landscape, suggesting that its margins may be larger or that distinct subpopulations exist in the Brazilian state of Rio Grande do Sul and possibly into northern Uruguay.	Iberá Nature Reserve, IUCN Category VI	300	60,718	0	11,190	0	11,190
20	Argentina. Includes populations in the subtropical savannas of Entre Ríos Province. Some exchange is expected with Corrientes Province (19) populations and potentially with Córdoba Province (18) populations.	No protected areas identified.	20	5,734	0	0	0	0

(*continued*)

TABLE 7.4. *Continued*

Landscape No.	Description	Representative Protected Areas (PAs)	Population estimate	Total Area	PA I–IV	PA V–VI	Other PAs	Total PAs
21	Argentina. Includes a small population, labeled Chaquito in Paula et al. (2008). Expected to exchange individuals with the Santiago del Estero (18) populations.	No protected areas identified.	10	844	0	0	0	0
22	Argentina. A newly described population in Paula et al. (2008). Potential exchange with Santiago del Estero (18) populations.	No protected areas identified.	15	1,119	0	0	0	0